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1 Preliminary Notes

1.1 Proprietary Notice

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Whilst every effort is made to ensure the accuracy, completeness and usefulness of the information in the document, neither Güralp Systems Limited nor any employee assumes responsibility or is liable for any incidental or consequential damages resulting from the use of this document.

1.2 Cautions and Notes

Cautions and notes are displayed and defined as follows:

Caution: A yellow triangle indicates a chance of damage to or failure of the equipment if the caution is not heeded.

Note: A blue circle indicates indicates a procedural or advisory note.

1.3 Manuals and Software

All manuals and software referred to in this document are available from the Güralp Systems website: [www.guralp.com](http://www.guralp.com) unless otherwise stated.

1.4 Conventions

Throughout this manual, examples are given of command-line interactions. In these examples, a fixed-width typeface will be used:

Example of the fixed-width typeface used.

Commands that you are required to type will be shown in bold:

Example of the fixed-width, bold typeface.

Where data that you type may vary depending on your individual configuration, such as parameters to commands, these data are additionally shown in italics:

Example of the fixed-width, bold, italic typeface.

Putting these together into a single example:

System prompt: user input with variable parameters
2 System Overview

Thank-you for purchasing a Güralp Fortimus digital accelerometer.

This section describes the key components of a Fortimus system. The Fortimus unit is the main, standard product in the system; other components and accessories are optional and can be purchased separately. Please check your order confirmation to see which components were purchased with your system.

2.1 Key features

- Digital, three-axis, strong-motion, force-feedback accelerometer.
- Flat response to ground acceleration from DC to 315 Hertz.
- Selectable gains for full-scale readings of ±4 g, ±2 g, ±1 g and ±0.5 g.
- 24-bit digitiser with a nominal sensitivity of 2.44 µV per count.
- Selectable sample rates from 1 sample per hour to 5000 sps.
- Data streaming in real-time using GCF (Scream!), GDI-link and SEEDlink.
- Compact form, measuring just 165 × 165 × 84 mm.
- Internal ±2 g MEMS accelerometer.
- Identification of I.P. address via Güralp Discovery software and, optionally, a cloud-based or organisational registry server.
- Remote instrument and data management via Discovery software.
- Android app for installation integrity checking via Bluetooth.
- Low-latency mode for Earthquake Early Warning (< 40 ms).
- Hot-swappable data storage with dual redundant 64 GB microSD cards.
- GNSS time-synchronisation, compatible with Navstar (GPS), GLONASS and BeiDou constellations, with PTP available as an alternative time-source.
- Touch-sensitive, 2.4 inch colour LCD for monitoring and control operations.

2.2 Typical applications

- Earthquake Early-Warning systems.
- Multi-scale seismic networks and arrays.
- Structural health monitoring (e.g. dams, industry, buildings).
- Surface and vault installation.
- Posthole deployment.
3 System description

3.1 Güralp Fortimus digital accelerometer

The Güralp Fortimus is a Fortis triaxial accelerometer combined with a Minimus digitiser. The Minimus acquires data from – and allows direct control of – the Fortis analogue instrument.

The labelled parts are:

- **A**: Hole for mounting bolt
- **B**: Status LED
- **C**: Touch-screen display
- **D**: WiFi antenna
- **E**: GNSS connection
- **F**: Cover for SD card
- **G**: Ethernet connection
- **H**: Power connection
The hard-anodised aluminium casing protects the instrument from water, allowing it to be deployed in a range of environments. Installation is simple, using a single fixing bolt to attach the sensor to a hard surface. If required, you can also level the sensor using its adjustable levelling feet. An integrated digital bubble-level – available in the display menu – provides quick visual feedback during levelling.

3.1.1 Liquid Crystal Display

The Fortimus is equipped with a multi-touch sensitive, 2.4 inch, full colour LCD touch-screen which shows waveforms and a virtual instrument level. Its menu system allows control of instrument state of health, gain settings and network configurations.

The LCD features are described in detail in chapter 5 on page 31.

3.1.2 LED indicator

The Fortimus has an LED indicator on the upper surface, which provides status and configuration information.

This information is encoded in sequences of coloured flashes. In general, red flashes indicate that initialisation is in progress or that the instrument has encountered a problem, green flashes indicate normal operation and blue flashes show trigger activity. The various codes are:

- **One quick red flash followed by a one second pause**: the removable microSD card is present in the Fortimus’ external slot, but no fixed microSD card is present inside the Fortimus.

- **Two quick red flashes followed by a one second pause**: the fixed microSD card is present inside the Fortimus but no removable microSD card is present in the Fortimus’ externally-accessible slot.
Three quick red flashes following by a one second pause: both microSD cards are present but either the GNSS receiver is disconnected or the GNSS lock is not sufficiently accurate.

A green flash every four seconds: this is the standard operating heartbeat. GNSS and both internal and external microSD cards are present, which indicates that the Fortimus can be successfully deployed and left to record data.

Note: Depending on the digitiser’s recent history, it can take up to ten minutes to reach this state after power-up.

1 blue flash: a trigger event has been detected.

3.1.3 Bluetooth connectivity

The Fortimus features Bluetooth connectivity, allowing sensor and state-of-health data to be monitored using the Güralp GüVü app (see section 3.4 on page 19) running on an Android mobile phone or tablet.

Bluetooth can be disabled via software to save processor usage but the hardware module cannot be switched off. BLE (Bluetooth Low Energy) technology is used to minimise the power requirement. The Bluetooth transmitter/receiver is in permanent standby mode and always ready to receive a connection from a phone or tablet.

See Chapter 8 on page 118 for further details on connecting to the Fortimus using a phone or tablet.
3.1.4 MEMS accelerometer

The Fortimus digital accelerometer is equipped with a triaxial Micro Electro-Mechanical System (MEMS) accelerometer with a measurement range of ±2 g. The three axes of sensitivity, Z, N and E, align with those of the main accelerometer outputs and are orientated as illustrated below:

3.1.5 Data storage

The Fortimus uses microSD (non-volatile) memory technology to store seismic data within the instrument. The Fortimus features two such microSD cards in order to provide redundancy; this helps to protect the recorded data in the unlikely event of any corruption or problem with the memory cards. One card is internal and cannot be removed by the customer; the other is hot-swappable and easily accessible without any technical knowledge.

The Fortimus is supplied with two microSD cards that are of equal storage capacity (e.g. two 64 GB cards).
3.1.5.1 Primary (removable / hot-swappable) microSD card slot

To remove a card, follow the sequence below:

The microSD card is protected by a screw-in cap, located next to the Ethernet connector and above the GNSS connector.

Remove the cap by unscrewing it anticlockwise, as shown.

Caution: Finger pressure is sufficient. Do not use tools.

The horizontal edge of the microSD card is now visible.

The card slot has a spring lock: pushing the card firmly inwards locks it into place; a second push releases the card so that it can be withdrawn.

Lightly push the edge of the microSD card with a fingertip or soft implement. Once the initial spring resistance has been overcome, the card will partially eject itself.
The card should now protrude enough that it can be grasped and withdrawn.

To replace the card, remove any existing card, as shown previously, and then:

Gently insert the replacement card into the slot with the logo facing upwards and the straight edge of the card on the left, as shown. The card must be perfectly horizontal in order to align properly.

Push the card gently into place until the pressure of the spring lock is felt. If it does not glide into place, remove and start again. Do not force the card.

Check that the card is fully engaged by pressing lightly to unlock it and then pressing to lock it again. The card should be engaged firmly when locked and slide freely otherwise. Ensure the card is locked before proceeding.

Offer the cap to the opening, taking great care to align the screw-thread correctly. Replace the cap by screwing it in clockwise, as shown.

**Caution:** Finger pressure is sufficient. Do not use tools.
Note: In order to ensure data integrity and security, Güralp only recommend using the supplied industrial-grade microSD cards.

Caution: When the external microSD card is removed, data will still be recorded to the internal card. However, these data are over-ridden when the external card is re-connected.

3.1.5.2 Internal (back-up) microSD card

The second microSD card is factory-installed in a slot inside the Fortimus.

Caution: The internal microSD card is not accessible by the user. Attempts to remove or replace it will void the Fortimus’ warranty.

3.1.6 WiFi connectivity

The Fortimus is provided with a Siretta Delta 7A omnidirectional antenna, suitable for both 2.4 GHz and 5.8 GHz networks.

The antenna connects directly to the Fortimus using an SMA connector. It can be removed and replaced with a high-gain, directional antenna if required. To remove, grasp the knurled locking sleeve and turn anti-clockwise, as shown.

See section 7.4 on page 47 for further details on how to configure the Fortimus to connect to a wireless network.

Note: It is not necessary to have the antenna fitted if wireless operation is not required.
3.1.7 Web interface

The Fortimus contains on-board firmware that presents monitoring and configuration interfaces. These are accessible through Güralp’s Discovery software (see section 3.3 on page 18) or, with the built-in web server, via Discovery’s browser interface or any standards-conformant web browser.

The web interface allows a number of instrument monitoring, control and configuration options:

- Sensor readings and instrument state-of-health
- Network configuration and authentication
- Sensor, timing, and station configuration/information
- Remote data-streaming configuration
- Local data-storage configuration

Please refer to Chapter 7 on page 44 for full usage instructions.
3.2 Accessory package

3.2.1 Ethernet cable

The Ethernet connector allows use of 10BASE-T, 100BASE-Tx or 1000BASE-T networks. The metal gland shell-type connector that connects to the Fortimus is IP68-rated and ensures consistent connection in harsh installation environments. At the other end of the blue Ethernet cable, there is a standard 8P8C modular jack (often incorrectly called an RJ45) for attachment to all common networking devices (e.g. PC, laptop, router, switch, modem etc.).

Please see section 12.1 on page 135 for the pin-out and further details.

3.2.2 Compact GNSS receiver and cable

The Fortimus is supplied with a new-generation compact GNSS receiver with an in-built antenna that supports the GPS (Navstar), GLONASS and BeiDou satellite constellations.

The receiver comes with a black RS-422 cable that has an over-moulded 14-way LEMO connector. LEMO connectors use an innovative latching mechanism which is different to the bayonet connectors used elsewhere. To mate, simply line up the red marks – one on the chassis and one on the free connector – and gently push the connector into place until they latch together with a click. To disconnect (un-mate), grasp the outer sleeve of the connector and pull gently.

Caution: Do not twist the connector or use any tools.

Please see section 12.3 on page 137 for pin-out details.
3.2.3 Power cable

The Fortimus comes with a dedicated power cable with a standard military-specification bayonet connector on one end and bare ends at the other.

**Note:** The Fortimus does not use a grey/blue combined power/data cable, as used with many other Güralp products.

Please see section 12.2 on page 136 for the pin-out details.

3.2.4 Diagnostic GNSS to Serial cable adapter

The Fortimus comes with an adapter to connect the GNSS LEMO connector to a female nine-pin D-subminiature connector (DE9f), which can be used with a standard serial port to allow diagnosis and debugging of the Fortimus using a serial terminal emulator. (See section 9 on page 124).

**Note:** This facility should rarely be required. It is primarily intended for use by the Güralp Support Team to help diagnose any problems with the Fortimus that may be experienced by the user.

A serial-to-USB converter (not supplied) may need to be used to connect to PCs or laptops that don’t have a nine-pin serial connector. Please see section 12.3 on page 137 for full pin-out details.
Güralp Discovery is a software application for seismometer configuration and control, state-of-health monitoring, and waveform viewing and acquisition.

An important benefit of Discovery is that it allows the user to identify the instruments' I.P. addresses on a LAN or via a cloud-based or organisational registry server without the need for static I.P. addresses at the stations.

Discovery also provides simple, convenient instrument and data management with access to hardware State-of-Health (SoH), data streaming; GNSS location; response and calibration data.

Discovery can download Fortimus firmware from the Internet and remotely install it onto any connected Fortimus.
3.4 Güralp GüVü Android and iOS app

For added confidence during deployments in the field, Güralp GüVü, a Bluetooth App, displays waveforms, orientation, temperature and humidity data for instant checking of installation integrity.

Please refer to Chapter 8 on page 118 for installation and usage instructions.
4 Getting started

4.1 Unpacking and packing

The Fortimus is delivered in environmentally-friendly, flat-packable, suspension packaging. The packaging is specifically designed for the Fortimus and should be re-used whenever you need to transport the sensor. Please note any damage to the packaging when you receive the equipment and unpack on a clean surface. The package should contain the digital accelerometer, the pigtail power cable, the GNSS receiver and cable, the Ethernet cable and the fixing bolt.

Caution: Although the Fortimus is a strong motion instrument, it contains sensitive mechanical components which can be damaged by mishandling. If you are at all unsure about the handling or installation of the device, you should contact Güralp Systems for assistance.

- Do not bump or jolt any part of the sensor when handling or unpacking.
- Do not kink or walk on the data cable (especially on rough surfaces such as gravel), nor allow it to bear the weight of the sensor.
- Do not connect the instrument to power sources except where instructed.
- Never ground any of the output signal lines from the sensor.
### 4.2 System set-up

Güralp highly recommends exploring and gaining familiarity with the Fortimus inside your lab before installation in an outdoors environment.

A typical set-up for the Fortimus is shown in the figure below:

To get started, connect the cables as shown in the figure above and as described in section 3.2 on page 16.

Power up the Fortimus using a power supply with a DC output of between 10 and 36 Volts.

**Caution:** Observe the correct polarity when connecting the power supply. The red lead (from pin B) must be connected to the positive terminal, typically labelled “+”, and the black lead (from pin A) must be connected to the negative terminal, typically labelled “-”. An incorrect connection risks destroying the instrument, the power supply and any connected accessories.

If the Fortimus is directly connected to a laptop or PC using the blue Ethernet cable, make sure that the laptop or PC is configured to obtain an IP address automatically. More details on how to correctly configure the connection using APIPA (Automatic Private IP Addressing) are in Appendix 5: section 14 on page 152.
4.3 Güralp Discovery software installation

To view live waveforms, and to control and configure the Fortimus, you will need to use Güralp Discovery software.


Download the installer appropriate for your architecture and operating system, run the installer and follow the instructions on screen. (Full details of installation and upgrading are in Appendix 2: section 13 on page 138.)

![Note: Windows users may have to reconfigure the Windows FireWall in order to allow Discovery to communicate properly. Please see section 13.4 on page 145 for full details. Brief instructions are below.]

Under Windows, the first time that you start Discovery, Windows may ask you to specify how you wish Discovery to interact with the Windows Firewall. Because Discovery requires network communication in order to function, it is important that you understand the options available.

The following screen is displayed:

![Windows Security Alert]

The screen provides three check-boxes which indicate whether Discovery can communicate with networked devices in the "Domain" profile, the "Private" profile or the "Public" profile. (Profiles are also known as “network locations”.)

The "Domain" profile applies to networks where the host system can authenticate to a domain controller. The "Private" profile is a user-assigned profile and is used to designate private or home networks. The default profile is the "Public" profile, which...
is used to designate public networks such as WiFi hotspots at coffee shops, airports, and other locations.


Once you have specified your firewall preferences, Discovery displays a main window which normally shows a list of both locally and remotely connected instruments. If you close this main window, Discovery will quit.

Discovery will initially "listen" for connected instruments on your local network. This mode can be refreshed by clicking the button or by pressing the short-cut keys + . These features are identified below:

You can add instruments to the list by right-clicking in the blank area and selecting "Add device" or choosing this option from the Edit menu:
The following dialogue is displayed:

Enter the IP address of the Fortimus (or other device, such as Güralp Minimus) to be added and click the **Add** button. The newly added device will appear in the device list.

**Note:** The newly added device will be removed from the list and not automatically re-added if a local network scan is performed.

You can choose which information is shown for each device in the main window. You can select which columns to display – and hide unwanted ones – by clicking on "Show" from the "View" menu.

The "Status" column is composed of three icons that represent the digitiser connectivity status (whether Fortimus is reachable/active or not), timing status (GNSS/PTP/PPS) and storage status (primary/secondary) respectively.
Hovering the mouse over any of these three icons will display tool-tips giving a brief description of the status including, for the timing indicator, details of which timing subsystems are operating:

4.4 Viewing waveforms and system state-of-health

Waveform data recorded by the Fortimus' internal sensors and other connected sensors can be viewed using several methods, which are described in the following sections.

4.4.1 Using Discovery's “Live View” window

4.4.1.1 Main features

Discovery offers a versatile live waveform/data viewer. To open the Viewer, in Discovery's main window, select an instrument and, from the View tab in the toolbar, select “Live View”. The menu will then present three options for data streaming:

• GDI and GCF channels
• GDI only
• GCF only

The GCF option uses the Scream! Protocol to stream data in GCF packets of, typically, 250, 500 or 1,000 samples. The GDI protocol streams data sample-by-sample and also allows the sending of each instrument's calibration parameters so that data can be expressed in terms of physical units rather than digitiser counts.

Güralp recommends using the “GDI only” option for waveform viewing.

The main features of – and the key buttons within – the Live View window are shown in the following screen-shot. Basic amplitude and time zoom functions are given in the Window zoom controls panel and streams can be easily added to or removed from the window by using the check-boxes in the left panel.
The channels are divided in groups with different hierarchical importance. The most important are the velocity/acceleration channels with higher sample rates: these belong to group 1. The least important belong to group 6, which includes humidity, temperature, clock diagnostics etc. When the live view is launched, only the channels in group 1 are selected. It is possible to change this setting by selecting a different group number from the “Select group up to” box at the bottom of the channel list.

When only few channels are selected for viewing, the channel name labels also show data statistics, including the maximum, minimum and average amplitudes in physical units.

If too many channels are in view for this information to be visible, you can left-click on a label and the label and trace will then expand to half the height of the screen, revealing these statistics. The other channels will be compressed into the remaining space. Another left-click on the same channel will return the window to normal. Alternatively, a left-click on a different channel will shrink the original one and expand the newly-selected one.
By selecting and dragging the mouse over a window of waveform data, the viewer will display similar statistics for the data within the selected window. When a window of data is selected, use the \[\text{Shift} \] key to subtract the ADC offset from the maximum, minimum and average values. Use the \[\text{Alt} \] key to calculate the integral of the selected data. By right-clicking on the window, you can perform advanced analysis on the data, including plotting power spectral density graphs (PSDs), spectrograms and discrete Fourier transforms (DFTs), as shown below:
4.4.1.2 Window control short-cuts

You can change the display of the waveforms with based on a combination of keystrokes and mouse-wheel scrolling (or track- / touch-pad scrolling on a laptop).

These commands are shown in the table below:

<table>
<thead>
<tr>
<th>Command</th>
<th>Window control</th>
</tr>
</thead>
<tbody>
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<td><strong>Amplitude control</strong></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="增加/减小所有波形幅度" /></td>
<td>Increase/decrease amplitude of all traces2</td>
</tr>
<tr>
<td><img src="image" alt="增加/减小某条波形幅度" /></td>
<td>Increase/decrease amplitude of individual trace</td>
</tr>
<tr>
<td><img src="image" alt="Ctrl + 滚轮调整通道标签" /></td>
<td>Shift individual trace offset up/down</td>
</tr>
<tr>
<td><strong>Time control</strong></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Ctrl + 滚轮调整时间轴" /></td>
<td>Pan time-scale right/left</td>
</tr>
<tr>
<td><img src="image" alt="滚轮调整时间轴" /></td>
<td>Zoom time-scale in/out</td>
</tr>
<tr>
<td><strong>Trace focus</strong></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="在波形标签上单击" /></td>
<td>Focus on individual trace</td>
</tr>
<tr>
<td><strong>Trace selection</strong></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="在波形标签上单击" /></td>
<td>Remove / de-select trace from Viewer window</td>
</tr>
<tr>
<td><strong>Details control</strong></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="在波形标签上单击" /></td>
<td>Reset the maximum and minimum values to the average value of the selected data</td>
</tr>
</tbody>
</table>

4.4.1.3 GDI connection settings

The GDI protocol allows a receiver, such as Discovery, to select which channels to receive by use of a “channel subscription list”. This feature can be useful in cases where the connection between Fortimus and Discovery has limited bandwidth. To subscribe to specific channels, right-click on a digitiser in Discovery's main window and select “GDI Configuration” from the context menu.

The resulting window has two very similar tabs. The “Subscription configuration” tab refers to channels selected for transmission and the “Storage configuration” tab affects which channels are selected for recording.
Click on the **Connect** button to connect to the Fortimus GDI server.

By default, Discovery subscribes to all channels. To alter this behaviour, change the radio-button from "Automatically subscribe to all available channels" to "Use subscription list". In subscription list mode, the channels in the list on the left-hand side are those to which Discovery subscribes. All available channels are listed on the right-hand side.

Channels can be moved between lists – *i.e.* switched between being subscribed and being unsubscribed – by using the arrow buttons on the middle:

<table>
<thead>
<tr>
<th>Button</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;&lt;</td>
<td>Subscribe to all channels shown in the <strong>Available channels</strong> list</td>
</tr>
<tr>
<td>&lt;</td>
<td>Subscribe to all selected channels in the <strong>Available channels</strong> list</td>
</tr>
<tr>
<td>&gt;</td>
<td>Unsubscribe from all selected channels in the <strong>Subscribed channels</strong> list</td>
</tr>
<tr>
<td>&gt;&gt;</td>
<td>Unsubscribe from all channels in the <strong>Subscribed channels</strong> list</td>
</tr>
</tbody>
</table>

**4.4.2 Using Scream!**

Data from the Fortimus can also be viewed and analysed using Güralp's Scream! Software.

For full usage information on Scream!, please refer to the on-line Güralp manual **MAN-SWA-0001**.
In Scream's Network Control window, add a UDP Server using the address reported under "LAN Address" in Discovery's main window (as described in section 4.3 on page 22).

Right-click on the newly-added server and select GCFSEND:B from the context menu. This sends a command to the Fortimus to start data transmission. Once the GCFSEND:B command has been issued, the instruments and their associated streams should begin to appear in Scream's main window.

To configure the Fortimus, double-click on its entry to open its web page.

**Note:** If stream recording is enabled, make sure that the file-name format in Scream! (on the Files tab of the File→Setup dialogue) is set to YYYY\YYYYMM\YYYYMMDD\I_A_YYYYMMDD_HHNN in order to prevent file names conflicting. More information can be found in Scream! manual MAN-SWA-0001 available on the Güralp website.
5 LCD Display menu

The Fortimus is equipped with a multi-touch, 2.4 inch (61 mm), full colour LCD display that shows the instrument’s state of health, inclination and real-time output waveforms. It also allows configuration of the instrument as well as some control operations.

While the Fortimus is booting up, it displays a white screen with the Güralp logo in the middle and a progress-bar at the bottom.

Once the Fortimus has booted up completely, the LCD automatically displays the “status” page.

To move back to the main menu, touch anywhere in the screen and the main menu will be displayed.

Note: When using the touch screen, keep your finger in place on each button for approximately half a second to ensure that your touch is registered. This delay helps prevent accidental triggering of menu functions. The LCD’s touch features can be disabled completely if desired: see section 5.6.3 on page 38 for details.

The complete LCD menu map is illustrated in Appendix 6: section 15 on page 155.

5.1 Main menu

The main menu offers the following options:

- status
- settings
- alignment
- waveform
- maintenance

These are discussed in the following sections.
5.2 Status

The "status" page shows information about serial number, Bluetooth status, time and date, GNSS/PTP status, input voltage and power, humidity, temperature, microSD cards recording status, I.P. address.

The top of the status display shows a series of icons:

These, from left to right, correspond to synchronisation (网站地图), GNSS location (GPS定位), WiFi reception (WiFi接收) and Bluetooth status (蓝牙状态). The icon does not appear if the relevant service is disabled. If the service is enabled but in a fault condition (i.e. not connected or no GPS fix found), the icon is shown with a line through it.

Warning and errors are shown here when necessary. Warnings are shown with an amber triangle on a grey background (警告三角), as shown on the left below. Errors are show with a red circle on an amber background (错误圆), as shown on the right.

The messages that can be displayed are:

- Normal operation:
  - **System OK**: GNSS or PTP are locked, microSD cards are recording.

- Warnings:
  - **Warning! SD card not fitted**: At least one of the microSD cards is not recording.
5.3 Settings

The "settings" menu offers the following options:

- display; and
- network.

These are discussed in the following sections.

5.3.1 Settings → display

The "display" page allow control of brightness, the inactivity time-out and the orientation of the display.

- The brightness can be set to be adjusted automatically, based on the ambient light level, or manually adjusted with the "lower" and "higher" buttons.
- The display can be set to stay on permanently (with a consequent increase in power consumption) or to automatically switch off after 5 s, 10 s, 30 s, 60 s or
120 s of inactivity. The currently-selected mode is indicated by the green background.

When the display has been switched off, it can be switched on again by touching and holding for a second.

- The orientation can be set to be normal or flipped. Selecting "auto-flip" will instruct the instrument to flip the display automatically based on attitude as determined by the internal MEMS accelerometer. The currently-selected mode is indicated by the green background.

5.3.2 Settings → network

The network page allows you to choose between DHCP mode, where the networking parameters are set by an external DHCP server, or static mode, where the network parameters must be typed in manually.

The current network mode is shown on the main status display:

If you select DHCP mode from the network page, you are asked for confirmation but no other configuration is required:
If you select static mode from the network page, you are prompted first for the IP address:

Enter the desired IP address using the on-screen virtual numeric keypad and then press "next", which takes you to the netmask screen.

Enter the desired netmask in the same way. Pressing "next" again takes you to the "Gateway IP" screen:

After entering the IP address of your gateway (default router), press "next" again to reach the confirmation screen:

Pressing "apply" here configures the Fortimus with the parameters that you have just entered. Pressing "cancel" discards all of the changes and the Fortimus' networking configuration is not affected.
5.4  Alignment

The "alignment" page shows a virtual bubble level based on the output of the MEMS accelerometer built-in the Fortimus. The red circle moves around the screen as the position of the Fortimus is altered, mimicking the bubble in a real bubble level; i.e. the red circle moves towards the highest part of the top of the instrument.

See section 6.1 on page 41 for more details about using the alignment tool.

5.5  Waveform

The "waveform" page shows real-time data in graphical format. The horizontal axis represents time and the display constantly scrolls to the left as the latest data are plotted on the right-hand side of the graph. Three modes are available:

- In "seismic" mode, the signals from the main acceleration outputs of the Fortimus are displayed.
- In "accel..." mode, the outputs from the internal MEMS accelerometer are displayed.
- In "auxiliary" mode, the display graphs the output from the internal temperature sensor, the internal supply voltage and the power consumption.
5.6 Maintenance

The “maintenance” page allows the user to:

- reboot the system;
- reset the configuration to factory values; and
- lock the “settings” and “maintenance” pages to prevent undesired alteration.

These are discussed in the following sections.

5.6.1 Reboot

This option reboots the processor in the Minimus digitiser without interrupting power. Because this will interrupt digitisation and potentially affect the configuration (some changes only take effect after a reboot), it is protected by a confirmation screen.

Click ⬇️ if you wish to continue and ⬆️ if you have arrived at this screen unintentionally and wish to return to the main menu.
5.6.2 Restore factory settings

This option restores the configuration to the state in which the instrument was delivered. Because this will interrupt digitisation and affect the configuration, it is protected by a confirmation screen.

Click if you wish to continue and if you have arrived at this screen unintentionally and wish to return to the main menu.

5.6.3 Lock the configuration

This option locks the LCD interface so that the instrument can only be reconfigured via its web interface. This can be useful when physical access to the instrument cannot be fully controlled. Because this can be disruptive, this option is protected by a confirmation screen.

Click if you wish to continue and if you have arrived at this screen unintentionally and wish to return to the main menu.

Note: Once “settings” and “maintenance” are locked, they can only be re-enabled from the Fortimus web page. See section 5.7 on page 38 for more details.

5.7 Controlling the LCD from the web interface

In the “Setup” tab of the Fortimus web page, the user can remotely control the LCD display settings.
Locking and unlocking of the “settings” and “maintenance” features can be selected using the drop-down menu named “Display settings”:

The display brightness is adjustable using the drop-down menu named “Display brightness”:

The display can be set to switch off after a selectable period of time while it is untouched. When the display is off, it can be switched back on by touching it for a couple of seconds.

The LCD is, by default, oriented with the top of the screen pointing North (relative to the instrument). The orientation can be flipped by 180 degrees if required or it can be set to “automatic”. When the auto-flip is enabled the orientation changes according to the MEMS output.

For security reasons, the LCD’s touch sensor can be disabled using the option “Touch sense”. Once disabled, touching the screen has no effect and no commands can be issued via the LCD.
To restore normal operation, set "Touch sense" to "Enable" from the Fortimus' webpage.

**Note:** "Touch sense" can be re-enabled *only* from the web interface. It is not possible to re-enable it using the LCD screen.
6 Installation

6.1 Permanent installation

You will need a hard, clean surface such as a concrete floor, to install the Fortimus.

If you are in any doubt about how to install the sensor, you should contact Güralp Systems' Technical Support, via support@guralp.com.

1. Prepare the surface by scribing an accurate N/S orientation line and installing a grouted-in fixing bolt on the line, near the middle. An anchor terminating in a 6 mm or 8 mm (1/4 or 5/16 inch) threaded stud is suitable.

   The exposed thread should project approximately 100 mm (4 inches) above the surface. Significant excess length should be removed.

2. Place the accelerometer over the fixing bolt and rotate to bring the orientation line and pointers accurately into registration with the scribed base-line.

   For more accurate alignment, a long, thin rod or a length of stiff wire can be aligned with a slot machined into the base of the instrument. It can be held in place by hand or, if preferred, by inserting two 3mm screws into the threaded holes provided.

3. Connect all the cables as described in Section 4.2 on page 21 and power on the Fortimus.

4. Touch the alignment button at the top right of the LCD screen: This will display the digital levelling tool.
The red circle behaves like the bubble in a traditional bubble-level, moving towards the highest edge of the instrument. The further from the centre it is, the more adjustment is needed.

5. Level the sensor, using its adjustable feet, until the red circle lies entirely within the inner circle of the indicator.

The feet are mounted on screw threads. To adjust the height of a foot, turn the brass locking nut clockwise (when viewed from above) to loosen it and rotate the entire foot so that it screws either in or out. When you are happy with the height, tighten the brass locking nut anti-clockwise to secure the foot.

6. Secure the instrument to the mounting stud using the conical washer provided and a wing-nut.

**Caution:** Hand-tighten only: do not use tools.

The instrument is now installed and transducing ground motion.
6.2 Temporary installations

The Fortimus is ideal for monitoring vibrations at field sites, owing to its ruggedness, high sensitivity and ease of deployment. Temporary installations will usually be in hand-dug pits or machine-augered holes. Once a level base is made, the accelerometer can be sited there and covered with a box or bucket. One way to produce a level base is to use a hard-setting liquid:

1. Prepare a quick-setting cement/sand mixture and pour it into the hole.
2. "Puddle" the cement by vibrating it until it is fully liquefied, allowing its surface to level out.
3. Follow the cement manufacturer’s instructions carefully. Depending on the temperature and type of cement used, the mixture will set over the next 2 to 12 hours.
4. Install the sensor as above, then cover and back-fill the emplacement with soil, sand, or polystyrene beads.
5. Cover the hole with a turf-capped board to exclude wind noise and to provide a stable thermal environment.

If you prefer, you can use quicker-setting plaster or polyester mixtures to provide a mounting surface. However, you must take care to prevent the liquid leaking away by “proofing” the hole beforehand. Dental plaster, or similar mixtures, may need reinforcing with sacking or muslin.

6.3 Installation in Hazardous environments

The fully enclosed, aluminium case design of the Fortimus makes it suitable for use in hazardous environments where electrical discharges due to the build up of static charge could lead to the ignition of flammable gasses. To ensure safe operation in these conditions, the metal case of the instrument must be electrically bonded ('earthed') to the structure on which it is mounted, forming a path to safely discharge any static charge.

Where electrical bonding ('earthing') is required during the installation of a Fortimus, the central mounting hole that extends through the instrument should be used as the connection point. This is electrically connected to all other parts of the sensor case. Connection can be made by either a cable from a local earthing point terminated in an 8 mm ring tag or via the mounting bolt itself.
7  Advanced system configuration

Advanced system configuration control and configuration tools are available by selecting an instrument in Discovery, right-clicking its entry and selecting “View Web Page”. Alternatively, the web interface can be viewed by navigating to the LAN address of the instrument from any common web-browser.

Note: Some changes in the settings require a system reboot to be applied. This is notified on the top right of the Fortimus web-page with the message Reboot Required. It is suggested to perform all the modifications and reboot the Fortimus when the configuration is completed clicking on any of the buttons.

7.1  System status

The "Status" tab of the web browser interface provides state-of-health information about the Fortimus. These parameters are described as follows:

- **Host name**: the serial number of the Fortimus;
- **Host label**: the customisable name of the Fortimus system;
- **System type**: the name of the connected digitiser, e.g. “Fortimus”;
- **Product type**: the type of the connected digitiser, e.g. “Fortimus”;
- **Temperature, humidity** and **pressure**: the internal temperature, humidity and pressure (not currently supported) of the Fortimus;
- **GNSS status, last GNSS timestamp, last GNSS lock time** since significant timing drift or re-boot, **GNSS stability** of the lock, **horizontal dilution of precision** (based on satellite coverage), **GNSS PPS status**, **GNSS NMEA stream**, **GNSS lock state** (2-D or 3-D), **number of satellites** used and in view;
- **Latitude, longitude** and **altitude** of the system, as provided by the GNSS receiver;
- **PTP state, last PTP timestamp, last PTP lock time** since significant timing drift or re-boot, **PTP stability** in time accuracy, **master IPv4 address** (I.P. address of the PTP master), **master clock class** and **accuracy**, **master time source**, **network path delay**, **network jitter estimate** (quality indicator in ns), **network outliers**;
- **MicroSD card** recording status, **total storage capacity, used storage space** and **available storage space**;
- **Real-time sensor values** from the accelerometer.
7.2 Station meta-data

Discovery provides a number of flexible station meta-data inputs. These are accessible from the “Setup” tab of the instrument’s web page.

“Label” is used in Discovery only and appears in the list of instruments in the main window. The Label can also be edited by right-clicking on the instrument in the main window of Discovery and selecting “Edit Label”.

“Station Name”, “Network Code” and “Site Name” are all standard meta-data header values used by the miniSEED file format, which will be included in locally-stored miniSEED files (see section 7.8 on page 52).

7.3 Network configuration

7.3.1 I.P. address and gateway

By default, the Fortimus uses DHCP (Dynamic Host Configuration Protocol) to acquire its network configuration but static addressing can be used if required.

To configure static addressing, visit the “Network” tab of the instrument’s Web page and, under “DHCP”, change the mode from “Enabled” to “Disabled” in the drop-down menu. In this mode, it is possible to specify the I.P address, the NetMask and the address of the Gateway (default router), as shown:
Before any changes made here will take effect, the Fortimus must be re-booted. To do this, click the button on the “Data Record” tab.

**Note:** By default, the static I.P. address assigned to each Fortimus is unique and derived from the specific serial number of the device. These addresses are in the default network for link-local (APIPA) addresses: 169.254.0.0/16 (in CIDR notation).

The first two bytes of the address, therefore, are always 169.254. The third byte is equal to the last two characters of the serial number interpreted as a hexadecimal number and then converted into base 10. The fourth byte is equal to the next-to-last two digits of the serial number, also converted from hexadecimal into base 10.

For example, if the serial number of the Fortimus is FMUS-C555, the preassigned Static I.P. address will be 169.254.85.197, where

- "C5" \(\Rightarrow (\text{C5})_{16} = (197)_{10} \Rightarrow 197\) and
- "55" \(\Rightarrow (\text{55})_{16} = (85)_{10} \Rightarrow 85\)

Network settings are also available in Discovery by right-clicking on the Fortimus’ entry in Discovery’s main window and selecting “Edit Network Address”.

### 7.3.2 NTP (Network Timing Protocol) configuration

**Note:** Network Timing Protocol (NTP) is only used for setting the system’s internal clock at boot-up, it is not used for sample timing. See section 7.10 on page 67 for details about synchronising the sample clock.

However: if neither GNSS nor PTP are available but NTP is locked and the sample clock’s time is more than five seconds different from NTP’s time, the sample clock will be adjusted (in a step-change) to NTP time.
By default, the NTP server option under the "Setup" tab of the instrument's web page is set to "Pool" which uses the virtual server pool pool.ntp.org. This accesses a dynamic collection of networked computers that voluntarily provide moderately accurate time via the NTP to clients worldwide.

Alternatively, it is possible to set the IP address of your preferred NTP server. To do this, select the “Static” option from the “NTP server” drop-down menu, which activates the “NTP IP Addr” setting; add your NTP server’s IP address here.

7.4 WiFi

The Fortimus can act as a WiFi client, connecting to an existing WiFi network. Both open and secure (WEP, WPA and WPA2) networks are supported.

**Note:** The Fortimus does not function as WiFi access point (AP) so it is not possible to connect a WiFi-enabled laptop, for example, directly to the unit. A separate WiFi AP is required in this case so that both laptop and Fortimus can connect to the same network.

The WiFi connection is configured and monitored from the “Network” tab of the Fortimus web page:
7.4.1 Connecting to a WiFi network

Visit the "Network" tab of the Fortimus web page and ensure that:

- the "WiFi Enable" check-box is ticked; and
- the "Auto Connect" check-box is clear as highlighted above.

Use the "Access Points" drop-down menu to select the desired network and enter the password or passphrase in the "Password" text field, if required.

Click the **Connect** button to connect to the network.

**Note:** A Fortimus connect to a WiFi network automatically appears in Discovery's "Scan Locally" section only when (a) the computer running Discovery is connected to the same WiFi network and (b) the Fortimus' Ethernet is disconnected or disabled.
7.4.2 WiFi connection status

The status of the WiFi connection is displayed at the top left of the WiFi section of the Network tab of the web page:

The possible values for the status are:

- **WiFi off** - the WiFi interface is disabled. Tick the "WiFi Enable" check-box to enable the interface, if required.

- **WiFi Standby** - the WiFi interface is enabled but not currently connected to any network. If no connection is required, clear the "WiFi Enable" check-box to disable the interface.

- **WiFi Connecting** - the WiFi interface is in the process of connecting to the selected network.

- **WiFi Connected** - the WiFi interface is connected to the network shown in the box below and the DHCP server has allocated the IP address displayed in the adjacent box. (Static IP addressing is not supported).

Once a successful connection is established, tick the “Auto Connect” check-box so that the Fortimus will attempt to reconnect to the same network whenever possible. The name of the selected network appears in the "Requested AP" box.

7.4.3 Changing WiFi networks

A different network can be selected from the "Access Points" drop-down menu - and the new password entered - while the Fortimus is still connected to a network. The instrument will not connect to the new network until the **Connect** button is clicked.

7.5 GDI push (auto-connection)

A Fortimus normally acts as a GDI server, where a client initiates a connection in order to pull data from it. This is the mechanism used when the GDI viewer in Discovery is launched.
The "GDI auto-connection" feature enables the Fortimus to establish *outgoing* network connections in order to *push* data to one or more remote clients, such as Platinum systems or an Earthworm system running the gdi2ew plug-in.

To configure an auto-connection, type either the I.P. address or the host-name of the target client, a colon (:) and the port number (*e.g.* 192.0.2.91:1566 or affinity10.example.com:1566), into any of the connection fields in the "Network" tab of the web page.

When auto-connection from a Fortimus to a host is configured, the Fortimus will attempt to open a connection to the host. If it fails, it will re-try every 60 seconds. A suitably configured host will accept the connection and the Fortimus will then negotiate a link and start streaming data.

If the connection drops, the Fortimus will attempt every 60 seconds to reconnect.

**Note:** The default port number for a GDI-link receiver is 1566. Push servers will normally connect to this port. The default port number for a GDI-link transmitter is 1565. Receivers wishing to pull data will normally connect to this port. See Chapter 11 on page 134 for a list of the network ports used by the Fortimus.
7.6 QSCD

The Fortimus can push data in QSCD format (Quick Seismic Characteristic Data) to one or more clients, using outgoing network connections.

To configure a connection, locate the QSCD section of the Network tab of the web page, as shown below. Type either the I.P. address or the host-name of the target client into any of the “Server” fields. This will push data using UDP port 9908, which is the default. If you wish to use a different port number, add a colon (‘:’) and the port number to the end of the specification. For example, 192.0.2.91:9876 or qscd.server.com:9876.

The Fortimus does not automatically send all data when using the QSCD protocol. Channels to be transmitted must be selected (in Z/N/E triplets) and each channel passed through a QSCD transform. See section 7.14.13 on page 95 for details on how to configure this transform.
7.7 Power monitoring

The “Power” tab of the Fortimus’ web page provides information about the supply voltage, as measured by the Fortimus. The Fortimus can be powered using either the power input connector (see section 12.2 on page 136) or via the Ethernet connection (see section 12.1 on page 135) using Power-over-Ethernet (PoE). The voltage measured at the PoE input is also displayed here.

![Power Supply Status](image)

7.8 Data storage

MicroSD cards need to be specifically formatted to operate with the Fortimus. The cards shipped with the Fortimus are supplied pre-formatted.

Data are stored on the microSD cards in miniSEED format. Each channel is saved as a series of 128 MiB files. Instrument and station meta-data (e.g. instrument response, coordinates, compression type etc.) are stored in "Dataless SEED" format.

The main panel of the "Data Record" tab in the web interface is shown here:

![Data Record Tab](image)

Options for monitoring and configuration of data storage can be found in the "Data Record" tab of the web page. This page is organised into three main panels: microSD status, card formatting controls and channel recording configuration.

The names and contents of each file are described in section 7.8.7 on page 57.
### 7.8.1 Recording status

The MicroSD card and data recording status can be monitored in the upper-most panel of the “Data Record” tab.

The left-hand column provides details of the external (primary, removable) microSD card and the right-hand column shows the status of the internal (backup) card.

Sections of this panel indicate the status of the following:

- Whether a card is inserted;
- Whether an inserted card is usable (i.e. correctly formatted); and
- Whether the card is recording data.

**Note:** If the recording status of the cards is marked **NOT RECORDING**, clicking on ‘Quick format cards’ or ‘Full format cards’ may solve the issue. Note that the quick format simply moves the write-pointer to the beginning of the recording space, hence overwriting any existing data. The full format, in contrast, erases all the existing data (and can take several hours).

### 7.8.2 MicroSD card re-formatting

The card re-formatting process fills the card with 128 MiB files containing zeroes. Each file is given a temporary, place-holder name. When data are written, these files are renamed and then over-written with data.

There are two methods for card reformatting: “Quick format” and “Full format”. The quick format mode should be used for pre-deployment tests (e.g. stomp/huddle tests) to ensure that the instruments are operating properly. This mode simply marks the existing files as empty without deleting their contents. Full formatting should be used prior to a long-term deployment to ensure that all headers are included and files are fully clean before writing.

The formatting process formats both fixed and removable cards, sequentially.
Note: A series of tests separated only by quick formats can leave some files with residual data in them. This is not normally a problem because a deployment will typically over-write any data remaining from the tests. The miniSEED extractor utility described in section 7.9.3.1 on page 66 can be used to remove the residual data if they cause any problems.

7.8.2.1 Quick format

Ensure that the external microSD card is correctly inserted. Click the button: a dialogue box will appear to confirm the formatting operation – click on button to continue.

The instrument web page will refresh and return to the “Status” tab. The reformatting operation is now complete.

7.8.2.2 Full format

Ensure the external microSD card is correctly inserted. Click the button and a dialogue box will appear to confirm the formatting operation – click on button to continue.

The process takes several hours: check the status countdown indicators on the top-right of “Data Record” tab.

Caution: Do not remove or insert the external microSD card while formatting is taking place.

7.8.3 Channel recording set-up

In the left-most column, drop-down boxes are available for each channel to either prevent the channel from recording (by selecting the “Disabled” option) or to select a sample rate. (You can stop all channels from recording by clicking the button).

After changing any sample rate(s), the Fortimus will need to be restarted before the changes come into effect; this can be done by clicking the button.
**FMUS-C456 is rebooting ...**

A minimal web page is displayed during the reboot and the LCD will show the starting-up sequence (see section 5 on page 31). Once the Fortimus has successfully restarted, the full web browser display/controls will be available again and their selected channels should start recording.

### 7.8.4 Viewing recorded data

The "Storage" tab of the web browser interface displays the miniSEED files stored on the microSD card:

![Screenshot of the Storage tab](image)

If the web page is accessed from a web browser, clicking on any file from the list automatically starts a single-file download using your browser's standard mechanism:
The microSD cards are formatted with empty files which are filled with data as they become available. The file-names are also changed when the files are written to. Until they are written to, they are marked as “hidden” files, so that it is easier to see how many files contain data when looking at the contents of the card.

### 7.8.5 Downloading data for specific time-intervals

Data for a single stream spanning a specific time-interval can be downloaded from the Storage page of the web interface. To do this, start by selecting the desired stream from the drop-down menu:

... then select the start and end dates and times using the pop-up calendars:
Lastly, click the [Download] button to initiate a file transfer using your browser’s standard mechanism.

**Note:** The pop-up calendars are not supported by Discovery’s built-in browser. The required dates can simply be typed in or the entire operation can be performed in an external web browser.

### 7.8.6 Bulk data extraction

To view files saved on the external microSD card, remove the card, as described in section 3.1.5.1 on page 12. Insert the card into a microSD card reader (external or in-built) on your PC/laptop. Within a few seconds, the card should appear as a removable disk/drive.

A microSD card formatted for the Fortimus contains many "hidden" files. They are created at format time with no contents and then renamed, unhidden and filled with data as required.

When viewing files in Windows Explorer, it may be helpful to configure your system so that "hidden" files are not shown. In Windows 10, this can be done by clearing the “Hidden items” check-box within the ribbon of Windows Explorer.

### 7.8.7 The contents of the microSD card

The root directory of the microSD card contains seven items:

- a file named **init.log**. This contains the first 32 MiB of system log information since the card was last formatted;

- a file named **system.log**. This contains the last 64 MiB of system log information;

- a file named **status.log**. This contains the last 32 MiB of dumps of system state of health information. A new dump is generated every 20 minutes.

- a disk image file which Güralp technical support may ask you to use if you have problems with the card;

- a file named **table_of_events.bin**. This is not human readable: it is used by the Seismic Events Table in the "Trigger" tab;

- a file named **network.DATALESS** where **network** is the two-character network code defined in Discovery (e.g. **GU.DATALESS**). This file is a Dataless
SEED volume that contains meta-data including instrument response, coordinates, compression type etc. The Dataless SEED volume is generated from the .RESP files for each channel;

- a directory named `all_miniSEED_files_are_in_here`. Within this directory, there will be a miniSEED file for each recording channel. The filename prefix is the same as the channel name description given in the “Data Record” tab. Each file is 128 MiB in size.
The typical contents of the `all_miniSEED_files_are_in_here` directory looks like this:

The file-name consists of four components:

- The stream name, truncated to 16 characters – see Chapter 3.1.5 on page 11 for a full list of these;
- The sample rate, (in samples per second), as a ten-digit decimal number, left-padded with zeroes;
- A number which functions as a counter to ensure unique name for all files. Each time a file is created, this number is incremented so that the next file to be created will use the next value; and
- The `.mseed` extension which identifies this as a miniSEED file.
The “Storage” tab also shows links to five auxiliary files, which are either saved in the Fortimus’ flash RAM or are dynamically generated:

<table>
<thead>
<tr>
<th>Filename</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DG.dataless</td>
<td>Dataless SEED file generated from the RESP files (dynamically generated). DG represents the user configurable network code;</td>
</tr>
<tr>
<td>fram.log</td>
<td>FRAM log file (stored in FRAM);</td>
</tr>
<tr>
<td>calvals.txt</td>
<td>calibration values in the format compatible with the Scream! Software package (dynamically generated);</td>
</tr>
<tr>
<td>polezero.txt</td>
<td>poles, zeros and normalising factors in the format compatible with the Scream! software (dynamically generated);</td>
</tr>
<tr>
<td>calib.txt</td>
<td>calibration text file with poles, zeros and gains expressed in hexadecimal base (stored in FRAM);</td>
</tr>
</tbody>
</table>

These files are

- **DG.dataless**: Dataless SEED file generated from the RESP files (dynamically generated). DG represents the user configurable network code;
- **fram.log**: FRAM log file (stored in FRAM);
- **calvals.txt**: calibration values in the format compatible with the Scream! Software package (dynamically generated);
- **polezero.txt**: poles, zeros and normalising factors in the format compatible with the Scream! software (dynamically generated);
- **calib.txt**: calibration text file with poles, zeros and gains expressed in hexadecimal base (stored in FRAM);

### 7.9 Data transmission

The monitoring and configuration of transmitted data is handled using the “Data Stream” tab of the instrument’s web page.

In most-left column, drop-down boxes are available for each channel to either select a sample rate or to exclude the channel from streaming (by selecting the “Disabled” option). All streaming can be stopped by clicking the button.
Upon changing the sample rate, the Fortimus will need to be restarted for the changes to come into effect; this can be done by pressing the button.

During the reboot, the LCD will show the starting-up sequence (see section 5 on page 31) and the Instrument Web Page will display the following screen.

**FMUS-C456 is rebooting ...**

Once the Fortimus has successfully restarted, the full web browser display and controls will be available for use again.

### 7.9.1 Scream! (GCF format + Scream protocol)

The Fortimus can act as a Scream! Server and streams data by sending GCF (Güralp Compressed Format) packets over a network connection using the scream data transmission protocol.

This is primarily intended to support Güralp's Scream! Software (see section 4.4.2 on page 29) or any software that can communicate using the Scream! Protocol, including SeisComP3.

These include:

- Güralp DM24 and CD24 digitisers with embedded acquisition modules (e.g. Güralp DM24SxEAM[U])
- Affinity digitiser
- Network Acquisition Module (Güralp NAM)

Data can also be received by software that can communicate using the Scream! Protocol, including SeisComp3 and Earthworm.

**Note:** Güralp devices running the Platinum software can receive GCF data over the scream protocol, but the GDI-link protocol is preferred in these cases.

### 7.9.2 GDI-link protocol

The Fortimus can also transmit data using the GDI-link protocol. GDI-link can currently be used with:

- Güralp instruments with embedded acquisition modules (e.g. STDE)
- Güralp DM24 and CD24 digitisers with embedded acquisition modules (e.g. Güralp DM24SxEAM[U])
• Güralp Affinity digitisers
• Güralp NAM (Network Acquisition Module)
• Earthworm software (www.isti.com/products/earthworm/)

GDI-link provides a highly efficient, low latency method of exchanging data via TCP between seismic stations and data centres. The protocol allows state-of-health information to be attached to samples during transmission. A receiver can accept data from multiple transmitters, and a single transmitter can send data to multiple receivers, allowing maximum flexibility for configuring seismic networks. GDI-link streams data sample-by-sample (instead of assembling them into packets) to minimise transmission latency.

A significant advantage of GDI-link is that it has the ability to stream data pre-converted into real physical units instead of just as raw digitiser counts, obviating a requirement for receivers to be aware of calibration values.

For more information on GDI-link, please refer to Güralp manual SWA-RFC-GDIL.

### 7.9.3 SEEDlink protocol

The Fortimus can act as a SEEDlink server to send miniSEED data packets over a network connection. The SEEDlink server is enabled by default but it can be disabled and re-enabled if desired. The server has a configurable back-fill buffer.

**Note:** The Fortimus SEEDlink back-fill implementation is packet-based.
Fortimus In the “Network” tab of the Fortimus’ web-page, select the desired SEEDlink mode.

The choices are:

- “Enabled” - This is the normal operating mode. Choose between backfill buffer sizes of 2 048 records, 65 536 records, 139 264 records or 622 592 records;
- “Disabled” - turns off the SEEDlink server; and
- “Debug” - this mode produces additional messages in the seedlink.log which may be helpful if trying to diagnose a problem. It is available with backfill buffer sizes as before and, additionally, 512 records.

Note: As a general guide, we find that 139 264 records is normally sufficient to store around one day of triaxial, 100 sps data.

Standard SEEDlink has a fixed packet size of 512 Bytes and each miniSEED packet is completely populated with data before it is transmitted. The Fortimus supports a modified version of SEEDlink that allows the transmission of incomplete packets. This improves latency.

Note: The modified SEEDlink is only available for EEW channels - i.e. the main seismic channels (generated with causal low latency filters) and the STA, LTA, STA/LTA ratio channels.
The user can specify the rate at which miniSEED packets must be transmitted. If populating complete packets would result in this rate not being achieved, incomplete packets are transmitted instead. The number of samples in each packet, therefore, depends both upon this setting and on the sample rate.

In the "Network" tab of the Fortimus web page select the interval in deciseconds (1 decisecond = 100 ms or 0.1 seconds) between miniSEED packets.

The modified SEEDlink protocol also allows the use of 256-byte records as an alternative to the standard 512-byte format. The "Data Record Size" drop-down menu on the "Network" tab of the Fortimus web page controls this behaviour.

**Note:** Not all SEEDlink clients can accept 256-byte records. Consult your client's documentation if in doubt.

To test the SEEDlink server, Güralp recommends using the `slinktool` software for Linux, which is distributed by IRIS. For more information and to download a copy, see [http://ds.iris.edu/ds/nodes/dmc/software/downloads/slinktool/](http://ds.iris.edu/ds/nodes/dmc/software/downloads/slinktool/).
To show a list of available miniSEED streams, issue the command:

```
slinktool -Q IP-Address
```

which produces output like the following:

```
DG TEST 00 CHZ D 2016-09-13 10:42:18 - 2016-09-13 10:46:56
DG TEST 00 CHN D 2016-09-13 10:42:18 - 2016-09-13 10:46:56
DG TEST 00 CHE D 2016-09-13 10:42:18 - 2016-09-13 10:46:56
DG TEST 00 MHZ D 2016-09-13 10:42:18 - 2016-09-13 10:46:56
DG TEST 00 MHN D 2016-09-13 10:42:18 - 2016-09-13 10:46:56
DG TEST 00 MHE D 2016-09-13 10:42:18 - 2016-09-13 10:46:56
```

To print miniSEED data records of a single channel, you will need the following command:

```
slinktool -p -S DG_TEST:00HNZ.D IP-Address
```

which produces the following output:

```
DG_TEST_00_HNZ, 412 samples, 100 Hz, 2016,257,10:43:42.000000 (latency ~2.9 sec)
DG_TEST_00_HNZ, 415 samples, 100 Hz, 2016,257,10:43:46.120000 (latency ~2.6 sec)
DG_TEST_00_HNZ, 416 samples, 100 Hz, 2016,257,10:43:50.270000 (latency ~3.0 sec)
DG_TEST_00_HNZ, 413 samples, 100 Hz, 2016,257,10:43:54.430000 (latency ~2.6 sec)
DG_TEST_00_HNZ, 419 samples, 100 Hz, 2016,257,10:43:58.560000 (latency ~3.0 sec)
DG_TEST_00_HNZ, 418 samples, 100 Hz, 2016,257,10:44:02.750000 (latency ~2.6 sec)
DG_TEST_00_HNZ, 415 samples, 100 Hz, 2016,257,10:44:06.930000 (latency ~3.0 sec)
```

The SEEDlink server on the Fortimus also supports the use of the "?" character as a wild-card within network, station and channel codes. This allows you to request multiple streams using a single command.

**Note:** Because the '?' character has special meaning to the shell, it is safest to quote this character with a preceding backslash ('\') when used in command arguments.
The miniSEED extractor serves two purposes:

- When an SD card is quick-formatted, each file is marked as unused but previously recorded data can still remain in them. Subsequent recordings overwrite these files from the beginning but, if the previous recording had a longer duration, old data will remain in the files. When the files are copied from the SD card to a PC, these older data can cause problems.

- The format used on the SD cards consists of fixed-length, 128 MiB files. Some recordings might not use all of this space. When the files are copied from the SD card to a PC, this can cause wasted disk space.

The miniSEED extractor reads miniSEED files on the PC and copies them to a selected Destination folder, keeping track of the latest block time-stamp as it goes. If it encounters either an unused block or a time-stamp which is earlier than the previous one, it stops copying, truncating the output file at that point. This guarantees that each output file contains only blocks in time order and contains no wasted space.

To use the tool, select “miniSEED Extractor” from the Edit menu. Click the first button to select which files you wish to process and then the second button to select the folder into which you wish the output files to be written. Finally, click the button to extract the valid data from the selected files into new files in the selected destination folder.
The same tool can also generate a report of any gaps in the data from the input files. To use, select the input files as before and then click [Gap Search] to view the report.

7.10 Synchronisation of the sample-clock

The Fortimus system synchronises its sample clock using an attached GNSS receiver or, if that is not available, Precision Time Protocol (PTP).

The currently supported GNSS systems are Navstar (GPS), GLONASS and BeiDou. If visibility of the satellite constellation is available, this is the most accurate way to synchronise your digitiser. The Fortimus accessory pack includes a combined GNSS antenna and receiver for this purpose: see section 3.2.2 on page 16 for details.

Precision Time Protocol (PTP) is a network protocol which uses modified network hardware to accurately time-stamp each PTP packet on the network at the time of transmission, rather than at the time that the packet was assembled. If you do not have an existing PTP infrastructure, the simplest way to use PTP is to add a "grand-master clock" to the same network segment as the digitisers. A typical such clock is the Omicron OTMC 100, which has an integrated GNSS antenna and receiver which it uses as its own synchronisation source. PTP timing can be extended over up to 100 metres of Ethernet cable or longer distances when fibre-optic cable is used.

**Note:** Although Network Timing Protocol (NTP) is used for setting the system's internal clock at boot-up, it is **not used for sample timing.** NTP is not, in general, accurate enough for this purpose. If it is impractical to use the GNSS receiver for synchronisation, PTP is the only viable alternative.

However: if neither GNSS nor PTP are available but NTP is locked and the sample clock’s time is more than five seconds different from NTP’s time, the sample clock will be adjusted (in a step-change) to NTP time.
7.10.1 GNSS lock status

This is available in the “Status” tab of the instrument’s Web page.

A number of GNSS reporting parameters are given, including:

- Connection status
- Last GNSS update (sync) & last GNSS lock date/time
- GNSS Stability:
  - 0% = no receiver connected;
  - 1% = receiver connected, but waking up (this can occur if the GNSS receiver has been moved a long distance since last power-up).
  - 2-99% = view of sky obstructed.
  - 100% = normal operation with clear view of sky
- Latitude, longitude, altitude
- Horizontal dilution of precision (quality of satellite fix due to position of satellites relative to receiver)
- GNSS PPS status
- GNSS NMEA streaming
- GNSS lock state (2D/3D)
- Number of available satellites (in use / in view)
7.10.2 Precision Time Protocol (PTP)

The Fortimus system supports timing provided through PTP.

The IEEE 1588 Precision Time Protocol is used to synchronise clocks across a computer network. It is significantly more accurate than NTP but generally requires specialised hardware support. PTP can be configured for multicast or unicast mode. In unicast mode, the server IP address must be specified.

This is available in the “Status” tab of the digitiser’s Web page. A number of reporting parameters are given, including:

- PTP state
- Last PTP time-stamp and last PTP lock date/time
- PTP Stability:
  - Standby ⇒ PTP is running but timing is provided by GNSS;
  - No Master ⇒ PTP not available;
  - 1-100% ⇒ PTP locking process indicator. 100% indicates a time accuracy of better than 200 ns.
- Master IPv4 address
- Master clock class and accuracy
- Master time source
- Network path delay
- Network jitter estimate: quality indicator
- Network outliers
7.10.2.1 Special notes for PTP when GNSS is not available.

In case PTP is the only source of timing available, configure it by visiting the “Network” tab of the Fortimus web page.

Under the heading “Network config” are four options:

- **Disabled** ⇒ PTP is never used (default settings).

- **Run if needed – Offline backup** ⇒ PTP is automatically enabled whenever the GNSS signal is lost. It is disabled while GNSS is available. This mode is used to minimise network traffic when GNSS is the primary timing source.

- **Run always – Online backup** ⇒ PTP is always running but GNSS is used as the primary timing source. This mode is useful for faster fall-back from GNSS to PTP timing and for validation that PTP is available.

- **Run always – Override GPS** = PTP is always running and takes priority over GNSS. This mode is useful in a system where PTP is the primary timing source, but GNSS may occasionally be connected for validation purposes.

Select the option “**Run always – Override GPS**” before the deployment of a Maris cabled system.

7.10.2.2 PTP offset corrections

If your PTP infrastructure produces a fixed offset (when compared with GNSS), a manual correction can be applied to compensate for this.
The required correction value can be extracted from the internal clock from GNSS stream of the Fortimus. In the Live View enable the $^0$CGPSO channel and select at least 20 minutes of data. Right-click on the selection and click on Show Samples:

At the top of the resulting window, the maximum ($\text{max}$), average ($\text{avg}$) and minimum ($\text{min}$) values are displayed:

Note the value of the average, multiply by -1 and enter the resulting value in the PTP Offset Correction box in the Network Timing section of the Network web page.

7.11 Deploy mode: Full power-save

The Fortimus offers two deployment modes: "Normal" and "Full power-save". "Full power-save" mode makes a number of configuration changes in order to reduce the unit's power consumption.
The desired mode can be specified using the “Deploy mode” drop-down menu in the “Setup” tab of Fortimus web page. Changes are not applied immediately.

The final step is to click on the Deploy button and confirm or cancel the operation from the pop-up window that appears.

A thirty-second count-down will start before the system enters power-save mode. The screen changes and a new button is added:

You can cancel the operation before the countdown is complete by clicking the Abort deployment button.

Caution: The power-save mode will disable the Ethernet and GNSS modules. You will not be able to continue to use the web interface.

Once in deploy mode, the only way to re-enable the Ethernet module is to connect to the Fortimus via a serial connection (see section 9 on page 124) or to use the GüVü Bluetooth app (see section 8.3 on page 120).
When a serial or Bluetooth connection is established, type the command `powersave off` in the console to disable the "Full power-save" mode and re-enable Ethernet communication.

7.12 Configuration and control of the accelerometer

7.12.1 Setting instrument (sensor) gain

The Güralp Fortimus strong-motion digital accelerometer features a remotely-switchable gain option that can be controlled from inside Discovery.

The gain is settable in the “Analogue Sensor” section in the “Setup” tab of the Fortimus' webpage. Under the “Instrument Gain”, select a gain setting (options: ±0.5 g; ±1 g; ±2 g; ±4 g).

Note: A reboot is required after this change.
7.12.2 Setting digitiser gain

The input gain can be controlled from the "Setup" tab of the web page using the "Input Gain" drop-down box. Digitiser gain options available are: Unity, ×2, ×4, ×8 and ×12.

The input range and resolution change automatically when the gain is selected and the gain in the RESP files and Dataless SEED is updated automatically.

7.12.3 Sensor centring

The Fortimus accelerometer automatically centres when it is powered up. To manually re-centre click on the Centre Mass button under the “Analogue Sensors” section in the Setup tab.
7.12.4 Output polarity

The polarity of output from each component of the instrument is as follows:

<table>
<thead>
<tr>
<th>Direction of ground acceleration</th>
<th>Polarity of Z output</th>
<th>Polarity of N/S output</th>
<th>Polarity of E/W output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upwards</td>
<td>positive</td>
<td>zero</td>
<td>zero</td>
</tr>
<tr>
<td>Downwards</td>
<td>negative</td>
<td>zero</td>
<td>zero</td>
</tr>
<tr>
<td>Northwards</td>
<td>zero</td>
<td>positive</td>
<td>zero</td>
</tr>
<tr>
<td>Southwards</td>
<td>zero</td>
<td>negative</td>
<td>zero</td>
</tr>
<tr>
<td>Eastwards</td>
<td>zero</td>
<td>zero</td>
<td>positive</td>
</tr>
<tr>
<td>Westwards</td>
<td>zero</td>
<td>zero</td>
<td>negative</td>
</tr>
</tbody>
</table>

If the ground accelerates northwards, this moves the casing of the instrument northwards and the N-axis inertial mass is left behind. From the instrument’s frame of reference, the mass appears to have been deflected southwards. The feedback system then needs to provide a balancing force to accelerate it northwards and this, by design, will result in a positive output signal from the N/S component.
If the instrument is mounted with the 'N' arrow pointing downwards, gravity will try and pull the inertial mass in the direction of the instrument's N-axis. The feedback system then needs to provide a balancing force to accelerate it upwards which, from the instrument's frame of reference, is now southwards. This is the opposite of the situation described above, so the output from the N/S component will now be negative.

The converses are also true: if the ground accelerates southwards, the instrument will produce a negative output signal from the N/S component and if the instrument is orientated with it's 'N' arrow pointing upwards, it will produce a positive output signal from the N/S component.

The polarity of the output signals with respect to acceleration can be demonstrated by selecting a sensitivity of 1 g, 2 g or 4 g and orientating the instrument as shown in the following diagram:
7.12.5 Instrument response parameters

Calibration is a procedure used to verify or measure the frequency response and sensitivity of a sensor. It establishes the relationship between actual ground motion and the corresponding output voltage. Calibration values, or response parameters, are the results of such procedures.

Response parameters typically consist of a sensitivity or "gain", measured at some specified frequency, and a set of poles and zeroes for the transfer function that expresses the frequency response of the sensor. A full discussion of poles and zeroes is beyond the scope of this manual.

The gain for a seismometer is traditionally expressed in volts per ms$^{-1}$ and, for an accelerometer, in volts per ms$^{-2}$. Other instruments may use different units: an electronic thermometer might characterise its output in mV per °C.

A calibration procedure is also used to establish the relationship between the input voltage that a digitiser sees and the output, in counts, that it produces. The results are traditionally expressed in volts per count. Each Fortimus is programmed at the factory so that it knows its own calibration values.

To explore the calibration values of the Fortimus' sensor and digitiser, right-click the Fortimus in Discovery's main window and select "Calibration" → "Calibration Page Editor". The resulting screen is shown here shortened:
This form has one tab for each seismic component. The instrument’s response values are:

- The **Digitiser Volts per Count (VPC)** - the ratio between the input voltage and the digitised output value (“counts”). This field will be populated automatically with the correct value for this input channel of the Firtimus.

- **Analogue/digital instrument gain** – this specifies the output voltage of the accelerometer per unit of ground motion in $\text{ms}^{-2}$, as measured at 1 Hertz.

- The **ADC offset** is the quiescent output seen when digitiser input is zero. This field will be populated automatically with the correct value for this input channel of the Fortimus.

- The **Coil constant** is the coil constant for the component being calibrated, in $\text{A/m/s}^2$, as given on the analogue sensor calibration sheet.

- The **Calibration resistor** is the value of the calibration resistor, in $\Omega$, as given on the sensor calibration sheet. This is common to all sensor components.

- The **Normalising factor** specifies the value that the transfer function (as specified by the poles and zeroes) must be multiplied by in order to provide unity gain at 1 Hz.

- The **Poles and Zeros** describe the frequency and phase response of the component. They must be specified in Hertz.

The calibration parameters for one component can be copied to any other component of the same instrument, or other instruments. This is especially useful for poles and zeros, because they are typically identical for all three components of all instruments in a class.

The drop-down menu in the “Component configuration” section allows selection of what to copy: poles and zeros, gains or everything. The destination sensor and component(s) can be selected in the subsequent drop-down menus. Click on the **Copy** button to copy and paste the selected values. Finally click on the **Send axis Z** button to send the calibration values to the digitiser and save them permanently. Repeat this last step for the other axis. Note that the **Send axis Z** button only sends the calibration of the selected axis.
The overall system calibration parameters can be exported and saved in a file for future use by clicking on the **Export to file** button under “System calibration values”.

The resulting file-name will have the extension `.conf`. Values from an existing calibration file can be imported using the **Import from file** button. The associated drop-down menu allows specification of what to import: poles and zeros, gains or everything. Click on **Send instrument calibration to device** to send the calibration values to the digitiser and save them permanently. Note that this action will only send the calibration of the selected sensor. Click on **Send to device** button to send the complete calibration to the digitiser.

When transmitting MiniSEED data, the responses of the instruments and digitisers are encoded in a message called a “Dataless SEED” volume. The contents of these volumes can be displayed in human-readable form, known as RESP, by clicking on the “RESP file” link of each channel in the “Data flow” and “Data record” tab of the Fortimus web page.
Clicking on a RESP file link produces a page like this:

```
#< Guralp SEED response file builder v1.2-0615 >
#-------------------------- CHANNEL RESPONSE DATA --------------------------
B050F03  Station: TEST
B050F10  Network: DG
B050F03  Location: OK
B050F04  Channel: MNZ
B052F22  Start date: 2018,214,11:26:48
B052F22  End date: No Ending Time
+  +  +  + Channel Sensitivity, TEST ch MNZ +
+  +  +  + +
B058F03  Stage sequence number: 0
B058F04  Sensitivity: 2.133148E+05
B058F06  Frequency of sensitivity: 1.000000E+00 Hz
B058F06  Number of calibrations: 0
+  +  +  + Response (Poles & Zeores), TEST ch MNZ +
+  +  +  + +
B058F03  Transfer function type: A [Laplace Transform (Rad/sec)]
B058F04  Stage sequence number: 1
B058F05  Response in units lookup: M/m*s**2 - Acceleration in Metres Per Second Squared
B058F06  Response out units lookup: V - Volts
B058F07  A0 normalization factor: 3.022930E+12
B058F08  Normalization frequency: 1.000000E+00
```

Right-click anywhere and select “Back” to return to the Fortimus web-page.

To save a RESP file, right click on it in the main list and select "Save Link“:

---

**Note:** RESP files are not available for channels that have a transform enabled. For details about transforms, see section 7.14 on page 82.
### 7.13 Setting sensor orientation and depth parameters

#### 7.13.1 Applied rotation

A Matlab extension for Scream! allows easy determination of the exact orientation of a sensor relative to a surface reference sensor (which can be accurately aligned magnetically or geographically). The procedure is explained at [https://www.guralp.com/howtos/determining-sensor-orientation](https://www.guralp.com/howtos/determining-sensor-orientation).

The Relative Orientation extension of Scream! provides a correction angle that can be entered into the Sensor Orientation section of the Fortimus web page.

![Fortimus Web Interface](image)

**Note:** The input rotation is automatically applied to both transmitted and recorded data.

#### 7.13.2 Instrument installation parameters

The Dip (tilt angle from vertical), Azimuth (tilt direction from North) and Depth of Fortimus can be set in the "Setup" tab of the web interface in the section "Instrument"
Installation Parameters”. The instrument to which the displayed parameters apply is selected using the drop-down menu.

**Note:** The orientation and depth are not applied to the data, the parameters are only saved in the Dataless SEED.

### 7.14 Transforms

The Fortimus is capable of applying mathematical transforms to the streamed and recorded data. These include low-pass and high-pass filters, integration, differentiation, rotation, STA/LTA trigger etc.

When a specific transform is activated on a particular channel, the resulting streamed (or recorded, accordingly to the chosen configuration) data output is automatically transmitted and/or recorded with the transform applied. The units-of-measure are re-calculated accordingly.

Transform functions are enabled or disabled from the “Data Stream” and “Data Record” tabs for each channel.
Note: To enable or disable a transform on any channel, it is necessary to reboot the Fortimus. Transforms can be applied only on enabled channels.

The available transforms are:

- Pass-through – see section 7.14.1 on page 84.
- Differentiation – see section 7.14.2 on page 84.
- 1st order low-pass filter – see section 7.14.3 on page 85.
- 2nd order low-pass filter – see section 7.14.4 on page 86.
- 1st order high-pass filter – see section 7.14.5 on page 85.
- 2nd order high-pass filter – see section 7.14.6 on page 87.
- 2nd order bi-quadratic – see section 7.14.7 on page 88.
- Integration – see section 7.14.8 on page 88.
- Double integration – see section 7.14.9 on page 89.
- EEW parameters observer – see section 7.14.10 on page 90.
- STA/LTA Trigger – see section 7.14.11 on page 92.
- QSCDx (triplet) – see section 7.14.13 on page 95.

Some transforms require parameters such as frequencies or coefficients. For these, the user can either use a fixed, default set, or create their own custom set.

To use customised parameters, visit the “Transform” tab and select the “Saved User Parameters” option in the “Parameter Source” drop-down menu. Type in the required parameters and then click to store them. It is possible to switch between Default and Saved User Parameters without altering the stored custom
parameters but clicking while “Default parameters” is selected will overwrite the customised parameters with the default values.

The various transforms are each described in the following sections.

**Caution:** The button at the top of the "Transform" column does not disable transforms for all streams. It stops transmission of all streams, which may not be what you intend.

### 7.14.1 Pass-through

This null transform simply outputs a copy of the input data, without applying any transform. It has no configuration parameters.

**Note:** This transform is selected by default when transforms are first enabled or when an invalid transform is selected. Do not use pass-through as a method of disabling transforms: instead, select "Disable transforms" from the drop-down menu next to each stream on the "Data Streams" tab,

### 7.14.2 Differentiation

This transform differentiates the input data, e.g. if the input is a velocity (ms⁻¹) channel, the output will be acceleration (ms⁻²). It has no configuration parameters.
7.14.3 1st order LPF

This transform applies a first-order low-pass filter to the input data.

The single configurable parameter is "Corner Frequency": this specifies, in Hz, the frequency at which the output power is attenuated by -3 dB. Above this frequency, output power is attenuated by a further 6 dB per octave or 20 dB per decade.

7.14.4 2nd Order LPF

This transform applies two sequential first-order low-pass filters to the input data.
The single configurable parameter is "Corner Frequency": this specifies, in Hz, the frequency at which the output power is attenuated by -3 dB. Above this frequency, output power is attenuated by a further 12 dB per octave or 40 dB per decade.

7.14.5 1<sup>st</sup> Order HPF

This transform applies a first-order high pass filter to the input data.

The output is the difference between a low-pass filtered copy of the signal and the unfiltered signal.

The single configurable parameter is "Corner Frequency": this specifies, in Hz, the frequency at which the output power is attenuated by -3 dB. Below this frequency, output power is attenuated by a further 6 dB per octave or 20 dB per decade.

**Note:** The high-pass filter is implemented by subtracting the output of a low-pass filter from the unfiltered data.
7.14.6 2\textsuperscript{nd} Order HPF

This transform applies two cascaded first order High Pass Filters to the input data.

The output is the difference between a low-pass filtered copy of the signal and the unfiltered signal.

The single configurable parameter is "Corner Frequency": this specifies, in Hz, the frequency at which the output power is attenuated by -3 dB. Below this frequency, output power is attenuated by a further 12 dB per octave or 40 dB per decade.

\textbf{Note:} The 2\textsuperscript{nd}-order high-pass filter is implemented by subtracting the output of two sequential 1\textsuperscript{st}-order low-pass filters from the unfiltered data:
7.14.7 2\textsuperscript{nd} Order biquad

This transform applies a second-order bi-quadratic filter to the input data.

\[ H(z) = \frac{b_2 + b_1 z^{-1} + b_0 z^{-2}}{a_2 + a_1 z^{-1} + a_0 z^{-2}} \]

The biquad filter is a second-order recursive linear filter, containing two poles and two zeros. In the Z-plane, the transfer function is the ratio of two quadratics in z, as shown.

The two configurable parameters are:

- "Corner Frequency": this specifies, in Hertz, the frequency at which the output power is attenuated by -3 dB; and
- "Type":
  - 0: low-pass mode; and
  - 1: high-pass mode.

7.14.8 Integration

This transform integrates the input data, e.g. if the selected channel unit is velocity (ms\textsuperscript{-1}), the output produced is displacement (m).

\[ H(z) = \frac{b_2 + b_1 z^{-1} + b_0 z^{-2}}{a_2 + a_1 z^{-1} + a_0 z^{-2}} \]

\[ \int dt \]

The integration transform is implemented as a configurable chain of three components:
• A DC filter (2nd order high-pass bi-quadratic) removes any DC component, which would cause the output to grow without limit;

• The integrator itself; and

• A 1st order high pass filter (implemented using an LPF and a subtractor, as described in section 7.14.5 on page 86), to gradually attenuate low-frequency integrator drift.

The configurable parameters are:

• "DC Cut-off Frequency": this specifies the -3 dB point (in Hertz) for the initial high-pass filter;

• "Output Cut-off Frequency": this specifies the -3 dB point (in Hertz) for the output high-pass filter;

• "Configuration Mode", which configures how many elements of the chain are used. The options are:
  ○ Apply only the initial DC filter;
  ○ Apply the DC filter and the integrator; and
  ○ Apply the DC filter, the integrator and the output HPF.

### 7.14.9 Double Integration

This transform integrates the input data twice so, for example, if the selected channel is acceleration (ms\(^{-2}\)), the output produced is displacement (m).
Analogously to the single integrator, the double integrator applies an initial DC high-pass filter and then two further high-pass filters, one at the output of each integrator. The high-pass filters are implemented using an LPF and a subtractor, as described in section 7.14.5 on page 86.

The configurable parameters are:

- "DC Cut-off Frequency": this specifies the -3 dB point (in Hertz) for the initial high-pass filter;
- "Interstage Cut-off Frequency": this specifies the -3 dB point (in Hertz) for the first integrator output high-pass filter;
- "Output Cut-off Frequency": this specifies the -3 dB (in Hertz) point for the second integrator output high-pass filter;
- "Configuration Mode", which configures how many elements of the chain are used. The options are:
  - Apply only the initial DC filter;
  - Apply DC filter and first integrator;
  - Apply DC filter, first integrator and interstage HPF;
  - Apply DC filter, first integrator, interstage HPF and second integrator; and
  - Apply DC filter, first integrator, interstage HPF, second integrator and second output HPF.

7.14.10 EEW Parameter Observer

When an EEW trigger occurs (or is simulated - see below), the peak ground motion values (Peak Ground Acceleration (PGA), Peak Ground Velocity (PGV) and Peak Ground Displacement (PGD)) are calculated and automatically recorded over the
selected time-window and subsequently transmitted as a CAP message (see Section 7.15 on page 96 for more details). This transform allows the operator to directly observe the PGA, PGV or PGD values during a configurable time-window of data. It is available for use with both velocity and acceleration input signals.

**Note:** This transform is intended to be used in conjunction with the Earthquake Early Warning (EEW) system. It should only be applied to low-latency, causal-filtered seismic channels (e.g. 0VELZC, 0AXLNC, etc.) that are used for EEW triggering.

The implementation of the transform differs, depending on whether the input stream represents velocity or acceleration data.

The high-pass filters are implemented using an LPF and a subtracter, as described in section 7.14.5 on page 86.

The configurable parameters are:

- "DC Cut-off Frequency": this specifies the -3 dB point (in Hertz) for the initial high-pass filter;
- "Interstage Cut-off Frequency": this specifies the -3 dB point (in Hertz) for the first integrator output high-pass filter. This is only used when the input signal is acceleration;
• "Output Cut-off Frequency": this specifies the -3 dB (in Hertz) point for the sole (velocity input) or final (acceleration input) integrator output high-pass filter;
• "Window time": this specifies the duration, in seconds, of the time-window over which the peak values are reported; and
• The values to be shown in the output stream:
  ◦ Peak Ground Acceleration (PGA);
  ◦ Peak Ground Velocity (PGV); or
  ◦ Peak Ground Displacement (PGD).

Note: Güralp recommend using the integration (section 7.14.8 on page 88) and double integration (section 7.14.9 on page 89) transforms to test the filter parameters, because the effect of the parameters will then be clearly visible in the transformed streams. Once suitable parameters have been determined, they can be copied to the EEW Parameter Observer transform.

Note: For testing purposes, a trigger can be simulated by setting the "Restart" option to 1.

7.14.11 STA/LTA Trigger

The Earthquake Early Warning system (EEW) compares the ratio of a short-term average (STA) to a long-term average (LTA) in order to detect "trigger" conditions. For more information see Section 7.15 on page 96.

This transform is included to help determine parameters for configuring the EEW system. It does not affect the operation of the EEW system in any way. The transform calculates the ratio between the result of the Short Term Average filter and the Long Term Average filter. The input signal is passed through a high-pass filter which removes any DC offset.
The configurable parameters are:

- "DC Frequency (Hz)": this specifies the corner frequency (-3 dB point) in Hertz for the initial high-pass filter;
- "LTA Period (seconds)": this is the Short Term Average filter time period (the reciprocal of the corner frequency);
- "STA Period (seconds)": this is the Long Term Average filter time period (the reciprocal of the corner frequency);
- "Trigger Threshold": this is the STA/LTA ratio threshold value above which a trigger will occur;
- "Event Window (Seconds)": this is the duration of the event after the STA/LTA trigger occurs; any subsequent threshold crossing within this period is treated as belonging to the same event. This can be used to avoid spurious false triggers.
- "Initial Timeout (Seconds)": this specifies an initial period of insensitivity after the trigger function is initialised or changed. This can be used to avoid spurious false triggers.

The high-pass filter is implemented using an LPF and a subtracter, as described in section 7.14.5 on page 86.

### 7.14.12 Three-dimensional rotation

This transform rotates three velocity/acceleration seismic components in space. Rotations are represented by unit quaternions (in preference to the more usual Euler angles: yaw, pitch and roll) because they are unambiguous and avoid the problem of gimbal lock.
**Note:** The rotation transform can only be applied if it is enabled in all three velocity/acceleration components of a single instrument at the same sample rate.

Any rotation in three dimensional space can be represented as a combination of a unit three-dimensional vector, \( \mathbf{u} \), which specifies the axis (and sense) of the rotation, and a scalar angle, \( \theta \), which specifies the amount of rotation.

Güralp follows a North, East, Up convention when describing sensor orientation. Using this convention, we can represent \( \mathbf{u} \) as \([u,v,w]\) and use Pauli’s extension to Euler’s formula:

\[
q = \cos \left( \frac{\theta}{2} \right) + (u \mathbf{i} + v \mathbf{j} + w \mathbf{k}) \sin \left( \frac{\theta}{2} \right)
\]

to form a quaternion: \( q \equiv [a, b, c, d] \)  

where:

\[
a = \cos \left( \frac{\theta}{2} \right), \quad b = \sin \left( \frac{\theta}{2} \right) u, \quad c = \sin \left( \frac{\theta}{2} \right) v \quad \text{and} \quad d = \sin \left( \frac{\theta}{2} \right) w
\]

For example, a perfectly-oriented sensor has a (null) rotation of \([1, 0, 0, 0]\), where the sensor’s Z, N and E axes align with the North, East and Up global axes.

A rotation of

\[
\left[ \frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, 0, 0 \right]
\]

represents a sensor that has been rotated 90° about its x axis to align the sensor’s Z, N and E axes with global North, Down and East respectively.

**Note:** Clockwise rotations, when looking along an axis, are denoted as positive. This is generally known as the "right-hand rule" because, if you point your right thumb along the (directed) axis, your fingers will curl in a clockwise direction about it.

In the degenerate case of a simple rotation about a vertical axis (commonly used to correct data from a misaligned borehole instrument), the axis of rotation is vertical, so our unit vector is \([0,0,1]\) (following the "North, East, Up" convention). To rotate by \( \theta \) (where positive \( \theta \) is clockwise when looking upwards), our quaternion should be:

\[
q = \cos \left( \frac{\theta}{2} \right) + (0 \mathbf{i} + 0 \mathbf{j} + 1 \mathbf{k}) \sin \left( \frac{\theta}{2} \right) \equiv \left[ \cos \left( \frac{\theta}{2} \right), 0, 0, \sin \left( \frac{\theta}{2} \right) \right]
\]
As a final check, note that
\[ a^2 + b^2 + c^2 + d^2 = \cos^2 \left( \frac{\theta}{2} \right) + 0^2 + 0^2 + \sin^2 \left( \frac{\theta}{2} \right) = 1 \]

which satisfies our requirement for a unit quaternion. The parameters to enter in the Configure Transforms fields are, therefore:

\[
\text{Scalar} \Rightarrow \cos \left( \frac{\theta}{2} \right), \quad X \Rightarrow 0, \quad Y \Rightarrow 0 \quad \text{and} \quad Z \Rightarrow \sin \left( \frac{\theta}{2} \right)
\]

7.14.13 QSCD (triplet)

The QSCD protocol (Quick Seismic Characteristic Data) transmits values computed from the three triaxial streams of an instrument. One packet is transmitted every second so the number of samples in each packet is equal to the sample rate of the three input streams.

QSCD calculations are implemented using transforms and configured via the Data Stream tab of the Fortimus’ web page. The three input channels must all be configured with the QSCD (triplet) transform. (The transform is disabled if the sample rates of the input streams do not match.)
In the Transform tab, the parameter “Period length” configures the number of samples to include in a QSCD packet. For example, QSCD20 requires the sample rate of the streams to be 20 sps so the “Period length” must be set to 20 (samples), in order to send a packet every second.

7.15 Earthquake Early Warning

The “Trigger” tab is dedicated to Earthquake Early Warning settings. These are disabled by default because of the amount of processing resource – and hence, power – consumed by triggering calculations. When enabled, the causal filtered taps are visible in the “Data Stream” tab.
The Earthquake Early Warning subsystem can be enabled using the drop-down menu at the top of the "Trigger" page of the web interface.

The heart of the Earthquake Early Warning subsystem is an STA/LTA (Short-Time-Average divided by Long-Time-Average) triggering algorithm. The algorithm continuously calculates the average values of the absolute amplitude of a seismic signal in two simultaneous moving-time windows. The short time average (STA) is sensitive to seismic events while the long time average (LTA) provides information about the current amplitude of seismic background noise at the site. When the ratio of STA to LTA exceeds a pre-set value (the parameters can be set, as seen in the picture below), an event is “declared”.

The following parameters can be configured:

- **DC Component Filter Coeff**: This parameter specifies the number of samples used to eliminate any DC offset. The formula used to calculate the time constant is shown on the far right column, where 200 is the sampling rate that is used in the internal STA/LTA processing. The default value of T, 1000, corresponds to a window of ≈ 5 seconds.

- **LTA Filter Coeff**: This parameter specifies the number of samples used to calculate the long term average. The formula used to calculate the time constant is shown on the far right column, where 200 is the sampling rate that is used in the internal STA/LTA processing. The default value of T, 500, corresponds to 2.407 seconds.

- **STA Filter Coeff**: This parameter specifies the number of samples used to calculate the short term average. The formula used to calculate the time constant is shown on the far right column, where 200 is the sampling rate that is used in the internal STA/LTA processing. The default value of T, 10, corresponds to 0.047 seconds.
• **Threshold Timeout**: This parameter specifies the time-out, in seconds, after a trigger is declared, during which the Fortimus will not accept any subsequent triggers.

• **Acceptance window**: When triggering from multiple sources (see below), this parameter specifies the time-out, in seconds, during which all of the sources must report a trigger condition before a multi-source trigger is declared. The time-out starts when the first event occurs. It is not reset when a subsequent event is reported.

When a trigger is declared, the system will issue messages using the Common Alerting Protocol. For the full specification of this protocol, please refer to [http://docs.oasis-open.org/emergency/cap/v1.2/CAP-v1.2-os.html](http://docs.oasis-open.org/emergency/cap/v1.2/CAP-v1.2-os.html).

Various parameters control how the CAP message is created.

These are:

• **Low Latency Mode**: Calculating triggering conditions is processor-intensive and affects the power-consumption of the Fortimus. This control can be used to prioritise power-consumption at the expense of latency, to balance the two or to optimise latency regardless of the power consumption. Three settings are available:
  - Minimum Power ⇒ slow processing / higher latency
  - Balanced ⇒ optimal
  - Minimum latency ⇒ fast processing / lower latency.

• **CAP Msg Expiry**: This parameter determines the value used to populate the optional “expires” field in the CAP message. If required, it should be specified in seconds.

• **CAP Msg Web URL**: This parameter determines the value used to populate the optional “web” field in the CAP message. It should be a full, absolute URI for an HTML page or other text resource with additional or reference information regarding this alert.

The Triggers section of the web page enables the user to configure the triggering system. The trigger source should be configured first because different configuration options are displayed for different source types. Once the source-specific settings are configured, the destination should be specified. Destinations can be shared between sources, allowing the creation of networks (directed graphs) of systems for distributed event detection. EEW parameters to be sent in the CAP messages can be enabled only for one source that belongs to each sensor. The EEW parameters sent
are PGA, PGV and PGD values and they have to be configured in the “Transform” tab (see Section 7.14.10 on page 90).

<table>
<thead>
<tr>
<th>Triggers</th>
<th>Seismic channels ZNE</th>
<th>STA/LTA Ratio threshold</th>
<th>Sensor 0</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Seismic parameters</td>
<td>Enabled</td>
<td>0.65535</td>
<td>109</td>
</tr>
<tr>
<td>EEE Parameters</td>
<td>Send EEE Parameters</td>
<td>Enabled</td>
<td>Destination: 1st CAP receiver</td>
<td>0.65535</td>
</tr>
</tbody>
</table>

7.15.1 Trigger sources

The available sources are listed below, along with the configurable fields available in each case.

- **Seismic Channel Z, N, E, N/E, Z/N/E**: seismic accelerometer channels based on the signals from either: single axis only (Z, N or E); either of the horizontal axes (N/E); or any axis (Z/N/E).

  The configurable fields in these cases are:

  - **STA/LTA Ratio threshold**: this specifies the trigger threshold. When the ratio of the short-term average to the long-term average exceeds this value, a trigger is declared.

    The streams SLRZ0, SLRN0 and SLRE0 expose the short/long term average ratio for Z, N, and E seismic channels, respectively. These can be monitored to determine a suitable value to specify as the threshold. In particular, general background values can be noted and compared to the maxima achieved during events of interest, as illustrated in the screenshot below.

  - **Sensor**: this specifies the sensor that will be used as the data source. For the Fortimus this option has always to be set as "Sensor 0".
○ **Score**: this assigns a number of points to this trigger. The points value is used when assessing multiple-source triggers. This value is ignored when a trigger is not configured to use multiple sources.

○ **Destination**: this drop-down menu specifies the destination for the trigger. See section 7.15.2 on page 101 for more information.

• **Accelerometer channel Z, N, E, Z/N/E, Z/N/E**: MEMS Accelerometer channels based on signal from: single axis only (Z, N or E); either of the horizontal axes (N/E), or any axis (Z/N/E)

The configurable fields in these cases are:

○ **STA/LTA Ratio threshold**: this specifies the trigger threshold. When the ratio of the STA to the LTA exceeds this value, a trigger is declared.

In the same way that the averages for the seismic channels are exposed, the streams SLXZ0, SLXY0 and SLXX0 expose the averages for the Z, N, and E MEMS acceleration channels, respectively.

○ **Sensor**: this specifies the sensor that will be used as the data source. For the Fortimus this option has always to be set as “Sensor 0”.

○ **Score**: this assigns a number of points to this trigger. The points value is used when assessing multiple-source triggers. This value is ignored when a trigger is not configured to use multiple sources.

○ **Destination**: this drop-down menu specifies the destination for the trigger. See section 7.15.2 on page 101 for more information.

• **1st/2nd/3rd/4th Remote source**: This setting is used for multiple-source triggering networks. The sources specified here are other Minimus digitisers or Fortimus, specified by the IP addresses configured in the “Inputs” section:

![Inputs Table]

The configurable fields in these cases are:

○ Score: this assigns a number of points to this trigger. The points value is used when assessing multiple-source triggers. This value is ignored when a trigger is not configured to use multiple sources.

○ Destination: this drop-down menu specifies the destination for the trigger. See section 7.15.2 on page 101 for more information.

• **1st/2nd/3rd/4th input**: Select this value to use inputs from a connected 8 channel I/O Expander Module.

The configurable fields in these cases are:
Güralp Fortimus

Advanced system configuration

- Score: this assigns a number of points to this trigger. The points value is used when assessing multiple-source triggers. This value is ignored when a trigger is not configured to use multiple sources.

- Destination: this drop-down menu specifies the destination for the trigger. See section 7.15.2 on page 101 for more information.

### 7.15.2 Trigger destinations

The options available form the various Destination fields are:

- **1st/2nd/3rd/4th CAP receiver:** Specifies that the trigger information should be sent to one of four defined CAP receivers. The receivers should be configured in the “Outputs” section:

<table>
<thead>
<tr>
<th>Outputs</th>
<th>Remote outputs</th>
<th>Relay outputs</th>
<th>Common Alerting Protocol Messaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st CAP Address</td>
<td>10.2.168.56.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st CAP Port</td>
<td>15769</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st CAP Threshold</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st CAP Msg scope</td>
<td>Restricted</td>
<td>1st CAP Recipient</td>
<td><a href="mailto:gump@gump.com">gump@gump.com</a></td>
</tr>
<tr>
<td>1st CAP Recipient</td>
<td></td>
<td>Total score</td>
<td>290</td>
</tr>
</tbody>
</table>

  - **CAP Address:** the IP address or DNS name of the CAP receiver
  - **CAP Port:** the UDP port on which the CAP receiver is listening
  - **CAP Threshold:** this is used when multiple input sources contribute to this trigger. The sum of the Scores of each input must exceed this value before the trigger is declared.
  - **CAP Msg scope:** This value is copied to the “scope” field of the CAP message.
  - **CAP Recipient:** This value is copied to the “addresses” field of the CAP message.
  - **Total score:** This is an information field. It displays an automatically-calculated total of the Scores from all of the input sources that specify this destination.

* See [http://docs.oasis-open.org/emergency/cap/v1.2/CAP-v1.2-os.html](http://docs.oasis-open.org/emergency/cap/v1.2/CAP-v1.2-os.html) for more information.

- **1st/2nd/3rd/4th/5th/6th/7th/8th relay:** Specifies that the trigger should be used to activate one of eight relays in a connected eight-channel I/O Expander Module output. The receivers should be configured in the “Outputs” section:

<table>
<thead>
<tr>
<th>Outputs</th>
<th>Remote outputs</th>
<th>Relay outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st threshold</td>
<td>0</td>
<td>1st timeout</td>
</tr>
<tr>
<td>1st total score</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>
Advanced system configuration

- **Threshold**: this is used when multiple input sources contribute to this trigger. The sum of the Scores of each input must exceed this value before the trigger is declared.

- **Timeout**: this specifies a time-out, in seconds, after which the relay is deactivated. A value of zero (0) specifies that the relay should latch and never be released.

- **Total score**: This is an information field. It displays an automatically-calculated total of the Scores from all of the input sources that specify this destination.

- **1st/2nd/3rd/4th remote receiver**: Specifies that trigger information should be sent to other Minimus or Fortimus units, as specified in the "Outputs" section:

<table>
<thead>
<tr>
<th>Outputs</th>
<th>Remote outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1st address</td>
<td>T1st threshold</td>
</tr>
</tbody>
</table>

  - **Address**: the IP address or domain name of the remote Minimus or Fortimus.
  - **Threshold**: this is used when multiple input sources contribute to this trigger. The sum of the Scores of each input must exceed this value before the trigger is declared.
  - **Total score**: This is an information field. It displays an automatically-calculated total of the Scores from all of the input sources that specify this destination.

### 7.15.3 Derived Streams

The various calculated averages used in the triggering algorithm can be displayed as streams in Discovery's live streaming window. This can be used to help decide appropriate triggering parameters. The available streams are:

- **0LTAZ0, 0LTAN0, 0LTEA0**: long term average for Z, N, and E seismic channels of the triaxial accelerometer

  **Mnemonic:** **LTA** ⇒ **Long Term Average**

- **0STAZ0, 0STAN0, 0STAE0**: short term average for Z, N, and E seismic channels of the triaxial accelerometer

  **Mnemonic:** **STA** ⇒ **Short Term Average**

- **0SLRZ0, 0SLRN0, 0SLRE0**: short/long term average ratio for Z, N, and E seismic channels of the triaxial accelerometer

  **Mnemonic:** **SLR** ⇒ **Short/Long Ratio**

- **0LTXZ0, 0LTXX0, 0LTXY0**: long-term average for Z, X, and Y from the internal MEMS accelerometer channels of a Fortimus. X corresponds to N and Y to E.
Mnemonic: \textit{LTX} ⇒ \textbf{Long Term average of X, where X ⇒ accelerometer}

- 0STXZ0, 0STXX0, 0STXY0: short-term average for Z, X, and Y from the internal MEMS accelerometer channels of a Fortimus. X corresponds to N and Y to E.

Mnemonic: \textit{STX} ⇒ \textbf{Short Term average of X, where X ⇒ accelerometer}

- 0SLXZ0, 0SLXX0, 0SLXY0: short-/long-term average ratio for Z, X, and Y from the internal MEMS accelerometer channels of a Fortimus. X corresponds to N and Y to E.

Mnemonic: \textit{SLX} ⇒ \textbf{Short/Long ratio of X, where X ⇒ accelerometer}

\textbf{Note:} Each time an event is detected and the trigger is enabled, the LED on the top of the Fortimus will flash blue once.

\section*{7.15.4 CAP receiver}

Güralp Discovery includes a CAP (Common Alerting Protocol) receiver. It listens on a specified UDP port for incoming CAP messages. When one arrives, it is displayed and plotted on a map. In addition, the receiver can open a TCP connection to the cloud-based registry server and display CAP messages that have been sent to the registry server. See section 7.16 on page 107 for information about configuring a registry server.

All CAP messages can be stored in a log-file. The full message is recorded so that it can be re-loaded later, if required.

The CAP receiver functionality is accessed using the context (right-click) menu in Discovery or clicking on “Edit” in the menu bar:

The CAP receiver window allows specification of the listening port. Each Fortimus from which messages should be received must have this value specified as the “CAP Port” in its triggering settings (see section 7.15.2 on page 101). The value should be between 1025 and 65535. You should avoid numbers in the list at \url{https://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers}. 
The reception of CAP messages can be enabled or disabled clicking on the button at the top, right-hand side of the window.

If you wish to forward the CAP messages to a server, type its IP address into the field and tick the check-box named "Use forwarding server". An error message is displayed if the entered IP address is not valid.

To log CAP messages to a file, tick the “Log events” check-box and use the button to select an appropriate location for the database file.

To import an existing database of events, first enable logging, then browse to the file using the button and, finally, click the button to load the file. If no file is specified, the logging is automatically switched off and a pop-up message is displayed.
When an event is detected and a CAP message is received, the location of the Fortimus that generated the trigger is identified by a pointer displayed on the map. The events and the information contained in the CAP message are displayed at the right-hand side of the window. This includes the SEED identifiers, network, station, channel and location, along with the time, the recipients and the threshold value which was exceeded.

If the EEW parameters are enabled in a particular source, after the first CAP message containing the event information, three other messages with the PGA/PGV/PGD details are sent, one for each component.

Click on the Clear events button to clear markers from the map and descriptions from the right-hand-side list. This action does not affect the contents of the log-file.

7.15.5 Seismic Event Table

The Fortimus can generate a “Seismic Event Table”. This is list of events detected by the STA/LTA transforms. It contains information about the time when the event occurred, its duration, the channel that generated the trigger and the peak magnitude of the event. The seismic data before, during and after the event are saved in miniSEED format and can be downloaded using links in the table.

The table is located at the bottom of the “Trigger” tab in the Fortimus web page.
Events will only appear in the list if one or more channels have been transformed using the “STA/LTA Trigger” transform (see section 7.14.11 on page 92 for more details).

**Note:** The Seismic Event Table is independent of the main triggering settings. Even if the EEW trigger is disabled, the table is still populated if STA/LTA transforms are enabled on any channels. The parameters of the STA/LTA calculations are configured via the “Transforms” tab. In order to obtain consistent lists of events detected using both the EEW trigger and the event table, we recommend setting the same parameters in both the “Trigger” tab and the “Transforms” tab.

The Fortimus allows the download of event data in miniSEED format in a time range that is user selectable. The user can select how many seconds before and after the event detection to include in the miniSEED file.

The event table shows which of the components has caused the trigger and the user can choose to either download data related to that single component by deselecting the option “Download Z, N, E Triplet” or download data for all three components by leaving the option enabled.

The last column of the table contains links to downloaded and saved miniSEED files related to each event.
7.16 Using a registry

Discovery can maintain a list of all Minimus and Fortimus units in a local or cloud-based registry, simplifying management of medium to large networks and removing the need for static IP addresses at telemetered stations. Registered digitisers appear in the selection list in the main screen, regardless of whether they are on the local network or not.

Administrators can create their own registry servers by installing a simple program on a server. The server itself must have a static IP address and be accessible to all connected Minimus/Fortimus units, as well as the PCs running discovery. Registry servers programs are currently available for Linux and Windows. Please contact Guralp technical support for details.

For administrators not wishing to install their own registry, Guralp provide a shared registry server in the cloud at 52.34.40.123 for customers to use.

Registered digitisers must be assigned to groups, each of which has a Group Identifier. Instances of Discovery must also be configured with a Group ID and can only display registered digitisers from the matching group. This allows partitioning of large networks into smaller administrative domains. It also makes possible the simultaneous use of the Guralp shared registry server by multiple organisations.

To use a registry:

1. Choose whether to use the Guralp shared registry or to deploy your own. If deploying your own, install the software on your chosen server and note its public IP address.
2. Choose one or more Group IDs for your digitisers
3. Set the Registry server address and Group ID in each Minimus/Fortimus
4. Set the Registry server address and Group ID in each instance of Discovery.

7.16.1 Configuring a Fortimus for use with a registry

The address of the registry server and the chosen Group ID must be set individually for each participating Fortimus.

To do this, first connect the Fortimus to the same network as a PC running Discovery and click the Scan Locally button, so that the Fortimus appears in the main Discovery list. Right-click on the digitiser's entry and select "View Web Page" from the context menu:
In the resulting web page, select the “Network” tab. The Registry parameters can be found near the bottom of the resulting screen:

These are:

- **Registry Update**: The frequency at which the registry is updated with details of this digitiser can be specified here, using the drop-down menu;

- **Registry Address**: The IP address of the registry should be entered here. To use the Güralp shared cloud server, enter 52.34.40.123.
• **Group ID**: The chosen Group Identifier should be entered here.

Once you have set the correct values, the digitiser must be rebooted before they will take effect. To do this, click the **Reboot** button.

### 7.16.2 Configuring Discovery for use with a registry

To specify a registry server for an instance of discovery, type its address into the field at the bottom left of the main screen:

To set the Group ID in Discovery:

1. Select "Settings" from the “File” menu:

2. Type the chosen Group ID in the “Cloud registry group identifier” field and click **Apply**.
Return to the main windows and test the configuration by clicking the button. All Fortimus using the same Registry server and Group ID should appear in the main list.

7.16.3 Registry mode: using WAN or LAN addresses

When Discovery displays a list of devices found from a local scan, all access to those systems is initiated via the LAN address. When displaying a list of registered devices, you have the option of using either the LAN address or the WAN address. This can be useful when the WAN address has been configured but is not yet available or when a registered device is installed remotely and not available on the LAN. The feature is controlled by exactly where you right-click in the list of devices.

If you right-click anywhere other than in the LAN address column, the WAN address is used and the behaviour is otherwise exactly as previously documented. To access the digitiser via its LAN address, right-click in the LAN address column, as shown below:
When you click on the LAN address of an entry, the context menu changes:

Entries for firmware updates, system and GDI configuration and web page access all now use the LAN address rather than the WAN address.

In addition, all options on the Live View sub-menu use the LAN address:
and the calibration page editor is also invoked using the LAN address:

![Image of calibration page editor](image)

**Note:** For these techniques to work, the digitiser and PC must be connected to the same LAN.

### 7.17 Updating Fortimus firmware

The firmware of the Fortimus is upgradeable. New releases appear regularly – mostly to add new features but, occasionally, to fix problems. Güralp recommends that the Fortimus is regularly checked for availability of firmware updates and, when convenient, these updates should be installed.

If you have any recorded data that you value, backup all files from the Fortimus microSD card:

1. Unplug the external microSD card from your Fortimus
2. Plug the external microSD card into your PC
3. Copy all files from the external microSD card into your PC
4. Unplug the external microSD card from your PC
5. Plug the external microSD card back into your Fortimus.

Once this is complete, to upgrade the Fortimus:

1. Run Discovery
2. Right-click on the Fortimus in Discovery main window and select “Firmware Update”.
3. In the “Firmware Update” tab, select “Guralp Server – stable (online version nnnn)” to obtain the new firmware from the Internet via a local Ethernet connection. Click **Get from server and update**.
4. Discovery will ask you if you want to save the Firmware binary file for future use

5. Discovery may ask to overwrite a temporary file on your PC – click Yes to allow it to do so.

6. Discovery will confirm through another dialogue box that the file download is complete. Click Yes to begin the firmware upload to the Fortimus.
7. A dialogue box will ask whether you are sure that you want to proceed with the update:

8. At the end of the uploading process, the dialogue box will ask to restart the Fortimus. Click **Yes** to finalise the process.

9. A dialogue box will ask you if you want to upload the previous configuration. Click **Yes** to finalise the process.

10. When the configuration is uploaded, the Fortimus needs to be restarted again. Confirm with **Yes** to the dialogue box.

11. The Fortimus will re-boot and, during this process, the LCD will show the boot-up screen (see section 5 on page 31).

12. Quick-format the microSD cards of your Fortimus (for details, see section 7.8.2 on page 53).

13. Go to the “Data Record” of the Fortimus web page
14. Click on the button

15. Click on the button.

16. Check that all indicators are green (i.e. nothing in red nor in yellow) in Discovery

17. Go to the “Status” tab of the Fortimus web page

18. Check that your Fortimus firmware version is as expected

19. Check that nothing red or yellow shows up in the “Status” tab of the Fortimus web page.

7.18 Import / Export an existing configuration

Updating the Fortimus’ firmware can, occasionally, cause loss of configuration. We recommend that you export and save the current configuration before proceeding with an upgrade. This operation can be done through Discovery by right-clicking on the digitiser in the list and selecting "System Configuration" from the context menu:

Select "Use configuration from one of the devices". If more than one device is available, select the one from which the configuration should be downloaded. Click the button and browse to a suitable location (on your PC) into which to save the configuration file.
After the firmware update is successfully completed, the previous configuration can be imported, if required, by following the instructions below.

Right-click on the digitiser's entry in the Discovery list and select "System Configuration" from the context menu. Select the "Use configuration from file" option.

Select the configuration file from where it was saved in the File Explorer and confirm. Use the check-boxes to select the devices to which the configuration should be uploaded and click on the Upload configuration button.

Wait until the process finishes. To apply the new configuration, the unit has to be rebooted: the Reboot selected button can be used to perform the required system restarts.
7.19 Control Centre

Several actions can be taken from within Discovery to control your Fortimus digital accelerometer.

These operations can be performed by right-clicking on the digitiser’s entry in the list and select “Control Centre” from the context menu. The meanings of the icons are given in the table below:

<table>
<thead>
<tr>
<th>Icon</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="State of health" /></td>
<td>This tab provides information about the general state of the instrument, its serial number and IP address, its up-time (time since last boot) and GNSS status.</td>
</tr>
<tr>
<td><img src="image" alt="Console" /></td>
<td>This button launches a console that allows interactions with the command line of the Fortimus. The list of available commands and their respective descriptions can be displayed by entering the command “help”. This should generally only be done on the advice of the Güralp technical support team.</td>
</tr>
<tr>
<td><img src="image" alt="Webpage" /></td>
<td>This button is equivalent to the “View Web Page” entry in the context (right-click) menu of the Fortimus in the Discovery main window.</td>
</tr>
<tr>
<td><img src="image" alt="Map" /></td>
<td>This button is equivalent to the “Show on Map” entry in the context (right-click) menu of the Fortimus in the Discovery main window.</td>
</tr>
<tr>
<td><img src="image" alt="Live view" /></td>
<td>This button is equivalent to the “Live View” entry in the context (right-click) menu of the Fortimus in the Discovery main window.</td>
</tr>
<tr>
<td><img src="image" alt="Centring" /></td>
<td>This tab allows manual centring of the Fortimus accelerometer.</td>
</tr>
</tbody>
</table>
8 GüVü app

The GüVü app provides monitoring and control of near-by Fortimus digital accelerometer using the Bluetooth protocol. It is available for both Android and Apple devices.

GüVü can be downloaded from the Google Play store at:


or from the Apple store at:

https://itunes.apple.com/us/app/id1208418113

8.1 Getting stated

To launch GüVü, follow the steps shown in the figure below:

Steps for launching the GüVü App:

1. Launch by clicking on the GüVü icon from either the Apps menu or from the Home Screen.

2. Wait a few seconds for the app splash screen.

3. Press the Bluetooth icon (.bluetooth) to enable Bluetooth connectivity (if not already enabled) and to search for available devices with which to pair.

4. Select the appropriate zFortimus device from the list of available devices. Wait a few seconds for the main viewer screen to show.

The instrument connection screen can also be accessed by pressing the menu icon ( SETTINGS ) on the main instrument status window, and selecting the “Connect” option.

If you experience problems connecting, try forcing GüVü to quit and then re-launching the app.
Once the device is connected, the main view of the app will be displayed. This screen displays a number of status indicators associated with both the digitiser and accelerometer. These features are summarised in the figure below:
Access the menu by pressing the menu icon (抻) on the main instrument status window:

8.2 View settings

The user can customise the view of the main instrument status window. Four different view options can be cycled through by tapping the menu icon (抻) on the main instrument status window:

- **Show all** – the default view setting; show state-of-health status, mass positions, and sensor traces on a single screen;
- **Show status view** – show state-of-health on the main screen only;
- **Show mass graph view** – show mass position traces on the main screen only; and
- **Show velocity graph view** – show sensor traces on the main screen only.

8.3 Instrument control

Several features of the Fortimus can be controlled and configured remotely over Bluetooth using GüVü:

- Accelerometer centring
- Clearing and un-mounting SD card
- Rebooting the Fortimus
- Enable/disable power-saving mode
- Station meta-data (User Label, Station Name, Network Code, Site Name)
- Network setting (I.P., Netmask, Gateway)
- Changing channels’ sampling rates

In each case, GüVü will report whether the selected command has been successfully sent to the device.

Note: After any modification to channels' sampling rates, the Fortimus must be rebooted before the changes will take effect.

These options can be accessed by tapping the menu icon (III) and choosing the "Device control" option. To access the instrument control and configuration sub-menu, a PIN code has to be entered by selecting the text entry box and tapping OK.
The default PIN code used to access the Instrument Control menu is "0000".

**Caution:** Güralp recommends changing the PIN code from the default, as described in the following section, in order to maintain station security.

### 8.3.1 Setting the PIN code

The PIN code for accessing the instrument control menu of GüVu can be changed from the "Setup" menu of Güralp Discovery. The new four-digit PIN code should be entered into the "Bluetooth PIN" field. The new value is applied by keying ENTER( ); or clicking the left mouse button in any other setting box.
8.4 Emailing a deployment report

The GüVü app has a feature that allows the user to generate an automatic deployment report that can then be filed via email.

The deployment report includes the following details:

- System name
- Station name
- Network code
- Instrument user label
- Memory card storage size and recording status
- Location of site (GNSS latitude, longitude, elevation)
- Time of deployment
- GNSS lock quality
- Power supply status
- Instrument temperature and humidity recordings

To send a deployment report, tap the menu icon (≡) and choose the "Deployment report" option. GüVü will then open the default email application on the device, showing a draft email which will include the parameters described above.
Advanced troubleshooting

In the unlikely event of the user experiencing problems with the operation of the Fortimus, a diagnostics tool is available via the GNSS connector, which also acts as a terminal communications device via a Serial connection.

The user should first plug in the serial adapter to the GNSS connector, which is then attached to a 9-pin COM port on your PC/laptop (if a 9-pin COM port is not available, a serial-to-USB converter should be used instead and connected to an available USB port. Güralp recommend converters based on the FTDI chip-set.)

A connection is then made using a terminal emulator, such as minicom under Linux or PuTTY under Windows. The appropriate COM port should be entered in the "Serial line" box and the Speed should be set to 115,200.

Finally click the button and a terminal window will open, connected to the console of the Fortimus.

In the event of any operational issues, the Güralp Support Team may request you to interact with the console in order to diagnose and fix problems.
9.1 Reset all settings during boot phase

The Fortimus can be reset to its factory settings during its boot-up stage. This is useful in cases where:

- the user is not able to communicate with the Fortimus via the LCD;
- the user is not able to communicate with the Fortimus via a network connection;
- the unit is not responsive; or
- the unit does not appear in the Discovery software's scan results.

To carry out a full system reset, connect to the terminal port via a serial connection (as described in section 9 on page 124). During the middle part of the boot phase, when the text `@GURALP SYSTEMS` and the firmware version number is displayed, key `Ctrl + R`. This causes all settings (except Username, Password and Bluetooth PIN) to revert to their factory default values, and the Fortimus will re-boot. It may be necessary to enter this key combination several times.

A typical boot log is shown below, identifying the stages where `Ctrl + R` will cause the Fortimus to reset and re-boot.

Do not press any buttons during the first phase of boot-up:

```
RomBOOT
SCKC_CR = 0x1, CKGR_MOR = 0x100FF0A, CKGR_PLLAR = 0x20FDD101,
PMC_MCKR = 0x1122, PIO_PDSR = 0xF03502F5
SCKC_CR = 0x1, CKGR_MOR = 0x100FF0A, CKGR_PLLAR = 0x20AC3F01,
PMC_MCKR = 0x0202, PIO_PDSR = 0xF2350065
AT91Bootstrap v3.8.10-1.guralp
NAND: ONFI flash detected
NAND: Manufacturer ID: 0x2C Chip ID: 0xDA
NAND: Page Bytes: 2048, Spare Bytes: 64
NAND: ECC Correctability Bits: 4, ECC Sector Bytes: 512
NAND: Disable On-Die ECC
NAND: Initialize PMECC params, cap: 4, sector: 512
NAND: Image: Copy 0x92000 bytes from 0xE000 to 0x2FA0E000
NAND: Done to load image
SCKC_CR = 0xA, CKGR_MOR = 0x100FF02, CKGR_PLLAR = 0x20AC3F01,
PMC_MCKR = 0x0202, PIO_PDSR = 0xF1350065
U-Boot v2017.03-2.guralp
CPU: SAMA5D36
External clock: 12.000 MHz
CPU clock: 528.000 MHz
Master clock: 132.000 MHz
```
I2C:  ready  
DRAM:  512 MiB  
NAND:  256 MiB  
MMC:  mci: 0  
In:  serial  
Out:  serial  
Err:  serial  
Net:  gmac0: PHY present at 7  
ctrl_sig_skew = 0x0017, rx_data_skew = 0x1222, tx_data_skew = 0x7787, clock_skew = 0x03FF  
Hit any key to stop autoboot:  0  
NAND read: device 0 offset 0x5C0000, size 0x360000  
3538944 bytes read: OK  
Uncompressed size: 4101060 = 0x3E93C4  
crc32 for 21000000 ... 213e93c3 ==> b9b1ab24  
Total of 2 word(s) were the same  
## Starting application at 0x21000000 ...  
t_who_called: Frame outside stack 20fffd74 [212d37a0 eafffffe]  
Board type set to: Fortimus  
Recognised external clock: 12000000 Hz  
SCKC_CR = 0xA, CKGR_MOR = 0x100FF02, CKGR_PLLAR = 0x20AC3F01,  
PMC_MCKR = 0x0202, MCK = 132000000 Hz  
t_who_called: Frame outside stack 20fffecc [212d37a0 eafffffe]  
t_who_called: Frame outside stack 20fffedc [212d37a0 eafffffe]  
@GURALP SYSTEMS  

Once the "@GURALP SYSTEMS" banner has been printed, keying Ctrl + R (at least once) will cause all settings (except Username, Password and Bluetooth PIN) to revert to their default values and cause the Fortimus to reboot.
Calling-> rpc_init
Calling-> ram_init
Calling-> ram_exchange_init
Calling-> system_update_init

If your key-strokes have been recognised, Ctrl+R will be printed in the boot log, as shown below – once for each time your keystrokes were logged:

Calling-> i2c_init
i2c_configure( 0, 100000Hz )
Using pclk 33000000, cdv 161, shift 0 => 100000
i2c_configure( 1, 100000Hz )
Using pclk 33000000, cdv 161, shift 0 => 100000
i2c_configure( 2, 400000Hz )
Using pclk 33000000, cdv 37, shift 0 => 402439
Calling-> i2c_dac_init
Ctrl+R
Ctrl+R
Ctrl+R
Ctrl+R
Ctrl+R
Calling-> i2c_humid_init
Humidity sensor test SUCCESS
Calling-> fram_init
Installing NVR device. size 12640
Calling-> net_sockets_init
Calling-> display_init
Calling-> aux_ioexp_init
Calling-> analog232_init
Calling-> start_timers
Calling-> chain_init
Using 251 coefficients.
Calling-> var_user_init
Calling-> calibration_init
Calling-> gcftx_init
Calling-> spi_datalink_chains_init
Sensor0 is accelerometer
Sensor1 is velocimeter
Sensor2 is velocimeter
Sensor3 is velocimeter
Sensor4 is velocimeter
Sensor5 is velocimeter
Sensor6 is velocimeter
Sensor7 is velocimeter
Sensor8 is velocimeter
Calling-> init_nand
Calling-> adc12_init
Calling-> init_random
Calling-> ltc4151_vc_monitor_init
Calling-> voltage_sniffer_init
Calling-> i2c_humid_init_ui
Calling-> adc12_init
Calling-> init_random
Calling-> ltc4151_vc_monitor_init
Calling-> voltage_sniffer_init
Calling-> i2c_humid_init_ui
Calling-> sd_Init
Calling-> sd_file_init
Calling-> sd_log_init
2007-01-01T00:00:10.000Z Retime Request Ignored: bad time
(35s/3600s/Boot delay)
Calling-> xtaltable_init
No XTAL table found.
Calling-> gps_pps_init
FMUS-8859-> Calling-> init_var_debug
Calling-> tcpdump_init
Calling-> var_html_init
Calling-> init_http_server
Calling-> sd_init_var
Calling-> gps_pps_ui_init
Calling-> xtaltable_ui_init
Calling-> init_fpga_datalink
Calling-> init_auto_center
Calling-> init_embedded_fs
Calling-> status_txt_init
Calling-> lan_init_web

#####tx_lock:
majic:f710f7f7
   Call_lock value:-1
   Calling-> init_responder_ui
Calling-> quasar_init
   Quasar Serial Isolated Input/Output Module support is disabled.
Calling-> quasar_init_ui
Calling-> applied_rot_init_web
Calling-> installation_parameters_init_web
Calling-> init_fortimus_web
Calling-> analog232_init_web
Calling-> eew_init_web
Calling-> triggers_init_ui
Calling-> spi_datalink_ui_init
Calling-> init_transforms
8.03 {transform.c;94} Transform configured/defined: Pass-through
8.04 {transform.c;94} Transform configured/defined: Pass-through
     DELAY
8.04 {transform.c;94} Transform configured/defined: 2nd Order
     Biquad
8.05 {transform.c;94} Transform configured/defined: 1st Order LPF
8.05 {transform.c;94} Transform configured/defined: 1st Order HPF
8.06 {transform.c;94} Transform configured/defined: Double
     Integration
8.07 {transform.c;94} Transform configured/defined: Integration
8.07 {transform.c;94} Transform configured/defined: Rotation
     (Triplet)
8.08 {transform.c;94} Transform configured/defined: EEW
     Parameters Observer
8.09 {transform.c;94} Transform configured/defined:
     Differentiation
8.09 {transform.c;94} Transform configured/defined: QSCDx
     (Triplet)
8.10 {transform.c;94} Transform configured/defined: STA/LTA
     Trigger
Calling-> chain_init_web
Calling-> transform_init_web
Calling-> gps_init

Once the boot-up reaches this stage, pressing Ctrl + R will no longer have any effect.
If $\text{[Ctrl]} + R$ was recognised during the second stage of boot-up, then the Fortimus will reset and re-boot:

Ctrl+R NVR load, resetting all vars to their default values and then rebooting

Forcing all vars to default values (including non-default-able)

PPS clock sources ACTIVE: 0x00000001  [GPS:0 PTP:0 RTC:0 TABLE:1]
PPS clock sources ACTIVE: 0x01000001  [GPS:1 PTP:0 RTC:0 TABLE:1]
PPS clock sources ACTIVE: 0x01010001  [GPS:1 PTP:1 RTC:0 TABLE:1]
PPS clock sources ACTIVE: 0x01010101  [GPS:1 PTP:1 RTC:1 TABLE:1]

Ctrl+R
Ctrl+R
Ctrl+R
sd_manager: probed both microSD card slots

11.58 {calibration.c;1142}  calibration_write_to_fram:
  successfully wrote calib to FRAM
11.60 {var_nvr.c;773}  'sd_format_time' $20301021 --> $00000000
11.61 {var_nvr.c;773}  'sd_unmount_time' $22647008 --> $00000000
11.62 {var_nvr.c;773}  'pps_src_table' 168 --> 1
11.63 {var_nvr.c;773}  'pps_src_gps' 0 --> 1
11.63 {var_nvr.c;773}  'pps_src_ptp' 69 --> 1
11.64 {var_nvr.c;773}  'pps_src_rtc' 132 --> 1
11.64 {var_nvr.c;773}  'rtcSavedOffsetSecs_nv' -1737983855 --> 0
11.65 {var_nvr.c;773}  'rtcSavedOffsetNano_nv' 402788896 --> 0
11.66 {var_nvr.c;773}  'rtcSavedFreqErrorPPB_nv' -2129883872 --> 1000000
11.67 {var_nvr.c;773}  'rtcSavedOffsetTime_nv' $52080158 --> $00000000
11.68 {var_nvr.c;773}  'xtaltable_offset' 610275339 --> 0

;
10 Appendix 1 – Instrument/channel names

The tables in this section show the names and codes of the streamed channels along with the record names and channel codes for recorded data. The first character “x” in miniSEED channel code represents the sample rate. The possible values are shown in the table below:

<table>
<thead>
<tr>
<th>MiniSEED channel code</th>
<th>Sample rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>≥ 1000 Hz to &lt; 5000 Hz</td>
</tr>
<tr>
<td>C</td>
<td>≥ 250 Hz to &lt; 1000 Hz</td>
</tr>
<tr>
<td>H</td>
<td>≥ 80 Hz to &lt; 250 Hz</td>
</tr>
<tr>
<td>B</td>
<td>≥ 10 Hz to &lt; 80 Hz</td>
</tr>
<tr>
<td>M</td>
<td>&gt; 1 to &lt; 10</td>
</tr>
<tr>
<td>L</td>
<td>≈ 1</td>
</tr>
</tbody>
</table>

The “Data record names” of the seismic channels and MEMS accelerometer channels are postfixed with “A” or “B”. This notation distinguishes between the two different sample rates that is possible to select for each recorded channel. For example, the recorded streams Sensor0AccelZRoughA and Sensor0AccelZRoughB carry digitisations of the same signal, differing only in the sample rate.

10.1 Environmental channels

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Comp.</th>
<th>Live stream name</th>
<th>Data record name</th>
<th>Mini SEED channel code</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEMS accelerometer</td>
<td>Vertical</td>
<td>Sensor0AccelZRough</td>
<td>Sensor0AccelZRoughA</td>
<td>xNZ</td>
</tr>
<tr>
<td></td>
<td>Vertical</td>
<td>Sensor0AccelZRough</td>
<td>Sensor0AccelZRoughB</td>
<td>xNZ</td>
</tr>
<tr>
<td></td>
<td>North</td>
<td>Sensor0AccelNRough</td>
<td>Sensor0AccelNRoughA</td>
<td>xNN</td>
</tr>
<tr>
<td></td>
<td>North</td>
<td>Sensor0AccelNRough</td>
<td>Sensor0AccelNRoughB</td>
<td>xNN</td>
</tr>
<tr>
<td></td>
<td>East</td>
<td>Sensor0AccelERough</td>
<td>Sensor0AccelERoughA</td>
<td>xNE</td>
</tr>
<tr>
<td></td>
<td>East</td>
<td>Sensor0AccelERough</td>
<td>Sensor0AccelERoughB</td>
<td>xNE</td>
</tr>
<tr>
<td>MEMS magnetometer</td>
<td>Vertical</td>
<td>Sensor0MagnetZRough</td>
<td>Sensor0MagnetZRoughA</td>
<td>xNZ</td>
</tr>
<tr>
<td></td>
<td>North</td>
<td>Sensor0MagnetNRough</td>
<td>Sensor0MagnetNRoughA</td>
<td>xFN</td>
</tr>
<tr>
<td></td>
<td>East</td>
<td>Sensor0MagnetERough</td>
<td>Sensor0MagnetERoughA</td>
<td>xNE</td>
</tr>
<tr>
<td>Long-term</td>
<td>Vertical</td>
<td>Sensor0XLTAvgZLowLat</td>
<td>Sensor0XLTAvgZLowLat</td>
<td>xNZ</td>
</tr>
</tbody>
</table>
## Appendix 1 – Instrument/channel names

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Comp.</th>
<th>Data streaming</th>
<th>Data recording</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average for Z, Y and X MEMS channels</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Acausal</td>
<td></td>
<td>Sensor0XLTAvgNLowLat</td>
<td>0LTXN0</td>
</tr>
<tr>
<td>East Acausal</td>
<td></td>
<td>Sensor0XLTAvgELowLat</td>
<td>0LTXE0</td>
</tr>
<tr>
<td><strong>Short-term average for Z, Y and X MEMS channels</strong></td>
<td>Vertical Acausal</td>
<td>Sensor0XSTAvgZLowLat</td>
<td>0STXZ0</td>
</tr>
<tr>
<td>North Acausal</td>
<td></td>
<td>Sensor0XSTAvgNLowLat</td>
<td>0STXN0</td>
</tr>
<tr>
<td>East Acausal</td>
<td></td>
<td>Sensor0XSTAvgELowLat</td>
<td>0STXE0</td>
</tr>
<tr>
<td><strong>Short/long-term average ratio for Z, Y and X MEMS channels</strong></td>
<td>Vertical Acausal</td>
<td>Sensor0XSLRatZLowLat</td>
<td>0SLXZ0</td>
</tr>
<tr>
<td>North Acausal</td>
<td></td>
<td>Sensor0XSLRatNLowLat</td>
<td>0SLXN0</td>
</tr>
<tr>
<td>East Acausal</td>
<td></td>
<td>Sensor0XSLRatELowLat</td>
<td>0SLXE0</td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
<td>Acausal</td>
<td>Sensor0VoltageRough</td>
<td>0VINP0</td>
</tr>
<tr>
<td>Power usage</td>
<td>Acausal</td>
<td>Sensor0PowerRough</td>
<td>0PINP0</td>
</tr>
<tr>
<td>Humidity</td>
<td>Acausal</td>
<td>Sensor0HumidARough</td>
<td>0HUMA0</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>Acausal</td>
<td>Sensor0TemprARough</td>
<td>0TMP A0</td>
</tr>
<tr>
<td><strong>Internal Clock</strong></td>
<td>Acausal</td>
<td>ClkGpsOffsetRough</td>
<td>0CGPSO</td>
</tr>
<tr>
<td><strong>Clock GNSS period rough</strong></td>
<td>Acausal</td>
<td>ClkGpsPeriodRough</td>
<td>0CGPSP</td>
</tr>
<tr>
<td><strong>Internal clock DAC frequency pulling</strong></td>
<td>Acausal</td>
<td>ClkDacFreqPullRough</td>
<td>0CVDAC</td>
</tr>
<tr>
<td><strong>Test internal clock drift</strong></td>
<td>Acausal</td>
<td>ClkTestPpbSRough</td>
<td>0CTSTB</td>
</tr>
<tr>
<td><strong>Internal clock</strong></td>
<td>Acausal</td>
<td>ClkPtpOffsetRough</td>
<td>0CPTPO</td>
</tr>
</tbody>
</table>
## Appendix 1 – Instrument/channel names

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Comp.</th>
<th>Data streaming</th>
<th>Data recording</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Digital filter mode</td>
<td>Live stream name</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offset from PTP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay MS</td>
<td>Acausal</td>
<td>ClkPtpDelayMSRough</td>
<td>0CPDMS</td>
</tr>
<tr>
<td>Delay SM</td>
<td>Acausal</td>
<td>ClkPtpDelayMRough</td>
<td>0CPDMS</td>
</tr>
<tr>
<td>Mean path delay</td>
<td>Acausal</td>
<td>ClkPtpMeanPathDelay</td>
<td>0CPMPD</td>
</tr>
</tbody>
</table>

### 10.2 Broadband accelerometer channels

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Comp.</th>
<th>Data streaming</th>
<th>Data recording</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Digital filter mode</td>
<td>Live stream name</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analogue accelerometer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>Acausal</td>
<td>Sensor0SeismoZSmooth</td>
<td>0ACCZ0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sensor0SeismoZSmooth</td>
<td>0ACCZ2</td>
</tr>
<tr>
<td></td>
<td>Causal</td>
<td>Sensor0SeismoZLowLat</td>
<td>0ACCCZ</td>
</tr>
<tr>
<td>North</td>
<td>Acausal</td>
<td>Sensor0SeismoNSmooth</td>
<td>0ACCN0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sensor0SeismoNSmooth</td>
<td>0ACCN2</td>
</tr>
<tr>
<td></td>
<td>Causal</td>
<td>Sensor0SeismoNLowLat</td>
<td>0ACCCNC</td>
</tr>
<tr>
<td>East</td>
<td>Acausal</td>
<td>Sensor0SeismoESmooth</td>
<td>0ACCE0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sensor0SeismoESmooth</td>
<td>0ACCE2</td>
</tr>
<tr>
<td></td>
<td>Causal</td>
<td>Sensor0SeismoELowLat</td>
<td>0ACCEC</td>
</tr>
<tr>
<td>Calibration channel</td>
<td>Acausal</td>
<td>Sensor0CalibSmooth</td>
<td>0CAL0</td>
</tr>
</tbody>
</table>

### Long-term average for Z, N and E seismic channels

| Vertical | Acausal | Sensor0LTAvgZLowLat | 0LTAZ0          |                    |                  |
| North   | Acausal | Sensor0LTAvgNLowLat | 0LTAN0          |                    |                  |
| East    | Acausal | Sensor0LTAvgELowLat | 0LTAE0          |                    |                  |

### Short-term average for Z, N and E seismic channels

| Vertical | Acausal | Sensor0STAvgZLowLat | 0STAZ0          |                    |                  |
| North   | Acausal | Sensor0STAvgNLowLat | 0STAN0          |                    |                  |
| East    | Acausal | Sensor0STAvgELowLat | 0STAE0          |                    |                  |

### Short/long-term average ratio for...

<p>| Vertical | Acausal | Sensor0SLRatZLowLat | 0SLRZ0          |                    |                  |
| North   | Acausal | Sensor0SLRatNLowLat | 0SLRN0          |                    |                  |</p>
<table>
<thead>
<tr>
<th>Sensor</th>
<th>Comp.</th>
<th>Data streaming</th>
<th>Data recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z, N and E</td>
<td>East</td>
<td>Acausal</td>
<td>0SLRE0</td>
</tr>
<tr>
<td>seismic channels</td>
<td></td>
<td>Sensor0SLRatELowLat</td>
<td></td>
</tr>
</tbody>
</table>

Güralp Fortimus

Appendix 1 – Instrument/channel names
## Appendix 2 – Fortimus network ports

The following network ports are used by the Fortimus:

<table>
<thead>
<tr>
<th>Port</th>
<th>Layer 4 Protocol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>TCP</td>
<td>HTTP server</td>
</tr>
<tr>
<td>1565</td>
<td>TCP</td>
<td>GDI transmission protocol</td>
</tr>
<tr>
<td>1567</td>
<td>TCP/UDP</td>
<td>GCF transmission protocol</td>
</tr>
<tr>
<td>4242</td>
<td>TCP</td>
<td>File exchange protocol</td>
</tr>
<tr>
<td>4244</td>
<td>TCP</td>
<td>Remote console</td>
</tr>
<tr>
<td>11788</td>
<td>UDP</td>
<td>Remote procedure calls</td>
</tr>
<tr>
<td>18000</td>
<td>TCP</td>
<td>SEED-link transmission protocol</td>
</tr>
</tbody>
</table>
12 Appendix 3 – Connector pin-outs

12.1 Ethernet

This is an Amphenol RJField-series 8P8C connector. It consists of a standard ISO 8877 8P8C modular socket (often called RJ45) in a bayonet mounting compatible with MIL-DTL-26482 (formerly MIL-C-26482).

<table>
<thead>
<tr>
<th>Pin</th>
<th>10BASE-T &amp; 100BASE-TX</th>
<th>1000BASE-T</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transmit Data +</td>
<td>BI_DA+</td>
</tr>
<tr>
<td>2</td>
<td>Transmit Data -</td>
<td>BI_DA-</td>
</tr>
<tr>
<td>3</td>
<td>Receive Data +</td>
<td>BI_DB+</td>
</tr>
<tr>
<td>4</td>
<td>not connected</td>
<td>BI_DC+</td>
</tr>
<tr>
<td>5</td>
<td>not connected</td>
<td>BI_DC-</td>
</tr>
<tr>
<td>6</td>
<td>Receive Data -</td>
<td>BI_DB-</td>
</tr>
<tr>
<td>7</td>
<td>not connected</td>
<td>BI_DD+</td>
</tr>
<tr>
<td>8</td>
<td>not connected</td>
<td>BI_DD-</td>
</tr>
</tbody>
</table>

This connector accepts unmodified ISO 8877 8P8C modular connectors (often called RJ45 connectors or Ethernet “Cat 5/6” connectors).

When used in hostile environments, a standard Ethernet cable can have a mating environmental shield (Amphenol part number RJF6MN) fitted.
12.2 Power

This is a standard 4-pin military-specification bayonet plug, conforming to MIL-DTL-26482 (formerly MIL-C-26482).

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Ground</td>
</tr>
<tr>
<td>B</td>
<td>10-36 V DC input</td>
</tr>
<tr>
<td>C</td>
<td>not connected</td>
</tr>
<tr>
<td>D</td>
<td>not connected</td>
</tr>
</tbody>
</table>

Wiring details for the compatible socket as seen from the cable end (i.e. when assembling).

Caution: Observe the correct polarity when connecting the power supply. The red lead (from pin B) must be connected to the positive terminal, typically labelled ‘+’, and the black lead (from pin A) must be connected to the negative terminal, typically labelled ‘−’. An incorrect connection risks destroying the digitiser, the power supply and any connected instruments.
12.3 GNSS/serial

This is a 14-pin LEMO EEG.1K socket. Suitable mating connectors can be found in the LEMO FGG.1K.314 range.

- To engage the mating connector, line up the red marks and push firmly home.
- To disengage, hold the mating connector by the gnarled outer sleeve and pull steadily.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>not connected</td>
</tr>
<tr>
<td>3</td>
<td>Ground</td>
</tr>
<tr>
<td>4</td>
<td>Debug (serial) receive</td>
</tr>
<tr>
<td>5</td>
<td>Debug (serial) transmit</td>
</tr>
<tr>
<td>6</td>
<td>not connected</td>
</tr>
<tr>
<td>7</td>
<td>GNSS power</td>
</tr>
<tr>
<td>8</td>
<td>GNSS pulse-per-second signal – RS-422 positive</td>
</tr>
<tr>
<td>9</td>
<td>GNSS receive – RS-422 positive</td>
</tr>
<tr>
<td>10</td>
<td>GNSS transmit – RS-422 positive</td>
</tr>
<tr>
<td>11</td>
<td>GNSS transmit – RS-422 negative</td>
</tr>
<tr>
<td>12</td>
<td>not connected</td>
</tr>
<tr>
<td>13</td>
<td>GNSS pulse-per-second signal – RS-422 negative</td>
</tr>
<tr>
<td>14</td>
<td>GNSS receive – RS-422 negative</td>
</tr>
</tbody>
</table>

Wiring details for the compatible plug, FGG.1K.314.*, as seen from the cable end (i.e. when assembling).
13 Appendix 4 – Güralp Discovery installation

Güralp Discovery is a software package for Microsoft Windows, MAC and Linux, which facilitates the identification, configuration and management of Güralp digitisers and instruments.

Güralp Discovery has a conventional .msi-based installer. Once installed, the software can check whether it is the current version and can update itself using a button on the Help→About menu.

13.1 Installation in Linux

The Linux version of Discovery 64-bit is delivered in a self-contained package.

To install Güralp Discovery:

1. Open the terminal
2. Visit www.guralp.com/sw/download-discovery.shtml to download the appropriate installation script or use the command
   
   `wget http://www.guralp.com/download/discovery/Discovery.run`

3. Make the downloaded file executable using the command
   
   `chmod +x Discovery.run`

4. Run the script with the `-h` option to see the installer's help message:
   
   `./Discovery.run -h`
   
   Online installer for Guralp Systems Discovery application
   Usage: ./Discovery.run [parameters]
   Parameters:
   -h : this message
   -i : perform installation
   -o <directory> : output directory (default /opt/guralp/discovery)

5. Execute the script, either accepting the default installation directory
   
   `./Discovery.run -i`
   
   or providing your own, alternative location
   
   `./Discovery.run -i -o /usr/lib/discovery`
The script proceeds through the following installation stages:

1. **A confirmation prompt:**
   
   Guralp Discovery will be installed in: /opt/guralp/discovery. [C]ontinue/[A]bort

   Type **C** to continue installation in listed directory, or **A** to abort and change directory using the `-o` execution parameter

2. **Downloading. The following message is printed:**
   
   Downloading Discovery from Guralp Systems server
   [Downloading]

   This step downloads the discovery package from the Guralp server. It is around 50 MiB in size so downloading may take a long time if you have a slow Internet connection.

3. **Next, the following message is printed:**
   
   Creating installation directory: /opt/guralp/discovery [OK]

   This step creates the installation directory. If an error occurs at this stage, please make sure that the user running the installation script has permission to create the specified directory.

4. **The downloaded archive is now unpacked into the specified installation directory. The following message is printed:**
   
   Unpacking Discovery to /opt/guralp/discovery [OK]

5. **The next step removes the downloaded file from the disk.**
   
   Removing downloaded Discovery archive [OK]

6. **A this point, the installation is complete. The message**
   
   Discovery is now installed in: /opt/guralp/discovery/discovery

   is displayed and the application is available in the specified directory.

### 13.2 Installation in Mac

To install Guralp Discovery in a macOS machine:

2. Either save the downloaded file on a local drive, or automatically open it with DiskImageMounter.

3. If you saved the file to disk, navigate to the download location and open Discovery.dmg with DiskImageMounter.
4. Successful mounting should result in the display of the Discovery drag and drop installation window:

![Discovery installation window]

5. Drag and drop discovery.app to the Applications folder.

6. When finished, the installation is complete and the Discovery app can be found in Launcher or Applications folder in Finder.
13.3 Installation in Windows

To install Güralp Discovery on a Windows machine:

1. Download the appropriate installer – 32-bit or 64-bit – from

2. Double-click the downloaded file. You may be asked whether you wish to
   continue: answer yes.

3. The following screen asks where, in the Start Menu, you would like to place
   the Discovery short-cut. The default location is normally satisfactory but you
   can change it from here if you wish.

   ![Select Start Menu Folder](image)

   Click Next, key ↑ or key Alt + N to continue.
4. The next screen asks whether you would like to place an icon for Discovery on the desktop:

![Image of setup screen]

Tick the check-box if you wish and then click [Next >], key [Enter] or key [Alt + N] to continue.

5. The installer then offers a last chance to change any of your decisions:

![Image of ready to install screen]

Click [Install], key [Enter] or key [Alt + I] if you are happy with your choices or click [< Back] (or key [Alt + B]) if you wish to revisit any of them.
6. Once you have clicked **Install**, the installation begins and a progress screen is displayed:

![Installation progress screen](image)

Pressing **Cancel** or keying **Esc** now will remove all of the installed files (except the installer itself) and reverse any changes made so far.

7. Once installation is complete, the following screen is displayed:

![Completion screen](image)

Press **Finish**, key **Enter** or key **Alt + F** to close the installer and launch Discovery.

**Note:** Discovery for Windows 64-bit requires Microsoft Visual C++ 2015. Discovery may ask to install it if it is not installed yet.
13.4 Configuring Windows Firewall

Windows Firewall can interfere with Discovery’s ability to send information to instruments and/or receive information from instruments over the network. If you use Windows Firewall, you should make special provision for allowing Discovery to communicate, as described in this section.

1. Click in the “Ask me anything” search box at the bottom left of your Windows screen:

2. Type “allow an app”

3. Select “Allow an app through Windows Firewall” from the search results.

4. Windows will display the “Windows Firewall Allowed Applications” screen.
   
   This displays a list of applications in alphabetical order. Each application is provided with three check-boxes which indicate whether the application can
communicate with networked devices in the “Domain” profile, the “Private” profile or the “Public” profile. (Profiles are also known as “network locations”.)

The “Domain” profile applies to networks where the host system can authenticate to a domain controller. The “Private” profile is a user-assigned profile and is used to designate private or home networks. The default profile is the “Public” profile, which is used to designate public networks such as WiFi hotspots at coffee shops, airports, and other locations.

For a more complete discussion of this topic, please see http://www.tenforums.com/tutorials/6815-network-location-set-private-public-windows-10-a.html or your Windows documentation.

5. First click the **Change settings** buttons to activate the interface.
6. Highlight the “discovery” line and then click the Details... button. The “Edit an app” window is shown:

7. Click the Network types... button. The “Choose network types” window is shown:

8. After making appropriate changes, click OK first in the “Choose network types” window, then in the “Edit an app” window, then in the "Windows Firewall Allowed Applications". This closes the Windows Firewall “Allowed Applications” tool and saves the changes that you have made.
13.5 Update

If a PC running Güralp Discovery has an Internet connection, Discovery can check whether an update is available. To initiate this, click About from the Help menu or type `Alt + H` followed by `A`:

A screen like the following is displayed:

The currently installed version is shown. If this is the most recent version available, the screen will say **Up to date** and the **Update** button will be disabled, as shown above. If a newer version is available, the screen will look like this:
If you wish to proceed with downloading the newer version, click the **Update** button. This does not commit to an immediate upgrade: it just downloads the installer. If you do not wish to download the installer, click **Ok** to close the “Discovery About” dialogue.

If you clicked **Update**, you may see the following warning if the previous installer is still in your download folder:

Simply click **Yes** or key **Enter** to continue: the download will start immediately.

While the download is in progress, the following indicator will be displayed:

When the download is complete, the following screen is displayed:
If you wish to complete the installation immediately, click **Yes**. If you would rather defer the installation, click **No** and run the installer at a more convenient time.

Once the upgrade is complete, start Discovery in the usual way. Windows, recognising that the program has changed, may ask you to specify how you wish Discovery to interact with the Windows Firewall. Because Discovery requires network communication in order to function, it is important that you understand the options available.

The following screen is displayed:
The screen provides three check-boxes which indicate whether Discovery can communicate with networked devices in the “Domain” profile, the “Private” profile or the “Public” profile. (Profiles are also known as “network locations”.)

The “Domain” profile applies to networks where the host system can authenticate to a domain controller. The “Private” profile is a user-assigned profile and is used to designate private or home networks. The default profile is the “Public” profile, which is used to designate public networks such as WiFi hotspots at coffee shops, airports, and other locations.

For a more complete discussion of this topic, please see www.tenforums.com/tutorials/6815-network-location-set-private-public-windows-10-a.html or your Windows documentation.
Appendix 5 – I.P. address configuration on PC or Laptop

With APIPA (Automatic Private IP Addressing), a laptop or PC can automatically configure itself with an IP address in the range 169.254.0.1 to 169.254.255.254. The default subnet mask is 255.255.0.0.

Connect the Fortimus to the laptop or PC using the blue Ethernet cable and power it up.

14.1 On Linux

On your Linux computer, open the terminal and type the command

```
sudo bash
```

Key and provide the appropriate password. Then, enter the command

```
ifconfig
```

to identify the Ethernet network interface to which the Fortimus is connected. Once you have identified the correct interface, connect the Fortimus, power it up and enter the commands

```
ifconfig wlp2s0 down
ifconfig wlp2s0 up
```

replacing `wlp2s0` with the name of the appropriate interface on your PC.

Enter the command `ifconfig` again to verify that the IPv4 address of the Ethernet adapter is now included in the network 169.254.0.0/16 - i.e. the address begins 169.154....

```
      flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
       inet 169.254.139.29  netmask 255.255.0.0  broadcast 169.254.255.255
            ether 94:65:9c:ab:3c:9a  txqueuelen 1000  (Ethernet)
        RX packets 55637  bytes 722823565 (689.3 MiB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 320424  bytes 42811910 (40.8 MiB)
        TX errors 0  dropped 0  overruns 0  carrier 0  collisions 0
```

In the example above, the interface has been allocated address 169.254.139.29, which is in the correct network.
14.2 On macOS

Click the Apple icon in the upper-left corner of the screen, and select "System Preferences."

1. Click the "Network" icon to open the Network Preferences pane and select "Ethernet" from the list on the left side of the window.

2. Click the gear button, , in the lower-left corner of the window, then click "Make Service Inactive." Click the "Apply" button to disable the NIC (Network Interface Card).

3. With the Fortimus connected and powered up, click the button again, click "Make Service Active" and click "Apply" to re-enable the NIC.

4. Check that the interface has been assigned an address in the correct network:

   ![Network connection status](image)

   In the example above, the interface has been allocated address 169.254.56.230, which is in the correct network.
14.3 On Windows

On a Windows computer, key + to open the "Run" dialogue, enter `ncpa.cpl` and key .

Right-click on the network adapter which is connected to the Fortimus and select “Disable” from the context menu. Right-click on the same adapter again and select “Enable”. Close the network settings window.

Key + and type , then . This opens a command window. Type the command `ipconfig` and verify that the IPv4 address of the Ethernet adapter is included in network 169.254.*.*.

![Command Prompt]

In the example above, the interface has been allocated address 169.254.56.230, which is in the correct network.
15 Appendix 6 - LCD menu map